INTEGRATION

REPORT OF WORKPACKAGE 5 OF THE FIRMA PROJECT

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SECTION 1. SUMMARY

Thames Case Study Team

In work package five (WP5) of the FIRMA project the focus is on the integration of the different case studies to determine what we have learned as a project. Originally, the idea existed that the project would results in an integrated modelling approach to all case studies. However, it was found over the course of the project that agent-based models were best developed as part of a participatory process focussing on case study problems, both in form and in content. Therefore instead of presenting an integrating framework, WP5 has focused on: compiling achievements in model interface design (Section 2); reviewing the generation and use of scenarios in project case studies (Section 3); comparing agent-based modelling approaches (Section 3); and drawing out key messages for water management as a result of our agent-based work (Section 4). Each section of the report provides an introduction to the aspect of integration being addressed and a discussion of project accomplishments, findings and limitations. The findings are based on case study submissions, included in the appendices to the report.

As a brief summary, the project has found that methodologically:

- Agent-based approaches allow the involvement of stakeholders in the development of models
- Agent-based approaches aid policy development by supporting stakeholder learning about the complex dynamics of water resources management and other stakeholders' viewpoints
- Agent-based approaches yield a richer base for policy-making than using traditional modelling approaches alone.
- Many agent-based models rather than a single common model are needed because the effects of water policy implementation differ according to context and history.
- There are many types of agent-based models and stakeholder participation so it is necessary to consider the most appropriate approach for a particular policy context.

- There are some common building blocks from which a variety of agent-based models can be constructed

This report works to underpin these methodological findings specifically with respect to the development and use of user interfaces and scenarios. The strengths of the case study approaches in realising the methodological advantages of ABM are also discussed. The benefits of pursuing these methodologies are discussed relative to the policy recommendations that can be formulated on the cross-case-study topics of water demand; risk management; and conflict management and consensus building.

We believe that the FIRMA approach (as described by work package reports WP1 – WP5) will lead to new ways of using participatory processes and integrated assessment models. This approach will allow for the clarifying and sharing of perspectives and the bottom-up development of social, political and natural representations to help us to develop a better understanding of what needs to be considered or controlled in order to influence behaviour.

SECTION 2. USER INTERFACES IN AGENT BASED MODELLING

Case compiled and introduced by David Hales, Centre for Policy Modelling, Manchester Metropolitan University

2.1 Introduction

Over the duration of the FIRMA project many models and tools (computational and non-computational) have been developed which interact in some way with various levels of user. In the Zurich case study work a number of tools were produced: A stakeholder "board game", an internet mediated "game" (used for eliciting information from stakeholders as part of the participatory process) and a computational model simulating stakeholder behaviour. In the Orb case study computational mediation tools were produced allowing stakeholders to interact and negotiate. In the Barcelona and Maastricht work, stakeholders can set various parameters (roughly equating to action they perform in the real world) and see possible outcome scenarios. The approach in the Thames case study is similar and the model and interface are currently being upgraded to improve stakeholder interaction and understanding. The models used have been discussed in detail in FIRMA Work Package Three (WP3).

This report provides an overview of the tools and methods used, key project findings and related technical issues and is summarised by a key conclusion and recommendation. Reports of the user interface developed in each case study (including details of software description, intended users and functions, design outline, evaluation and key case study findings) can be found in Appendix A1.

2.2 Kinds of Tools and Models

It is important to make clear (as was made clear in WP3) that none of the models are concerned with prediction of actual outcomes – this is not the motivation or utility of the models. The models and tools presented here are concerned with capturing and eliciting stakeholder behaviour in complex multi-agency environments. To this end they form an integral aspect of the participatory process that has been a key outcome of the FIRMA project as a whole.

We can delineate two categories of tools and models presented in this chapter based on user profile:

- Models and tools produced for use only by the researchers within the FIRMA project themselves – to aid their understanding of stakeholder processes.
- Models and tools produced for use directly by stakeholders for knowledge elicitation and / or stakeholder learning processes.

In the latter category, the design, evaluation and key lessons learned concerning the user interfaces is an important and unique contribution that is documented in this chapter.

2.3 Key Findings

Based on the actual experiences of the five regional case studies outlined here the following key points can be made with respect to the latter category of models and tools:

- Different user interfaces are often required for different stakeholders.
- Early application of graphic design principles is crucial for effective interface design.
- Many iterations of user testing are required to make a good interface.
- If possible, familiar graphical metaphors (as already known by stakeholders) should be utilised.
- Stakeholders may be involved in the co-design of a model through discussion around the interface.

2.4 Technical issues

In this chapter we have not focused too much on the technical aspects of the GUI (Graphical User Interface) programming. Such issues are dealt with at length in technical programming texts. However, in each case study (see Appendix A1) a brief technical section acknowledges and lists the source of any third party libraries or tools employed.

2.5 Conclusion

One overall conclusion from the case study reports (Appendix A1) is that good user interfaces are key to the success of a participatory approach and that production of such interfaces is costly in time (both programmer and stakeholder) and ideally involves rapid prototyping and the application of graphic design principles.

A recommendation emanating from the FIRMA project is that future projects involving stakeholder engagement should allow for several iterations of prototyping within the life span of the project. User interfaces should not be viewed as an afterthought, something to “bolt onto” a model after it is constructed, but as an integral aspect of the participatory approach.

SECTION 3. SCENARIOS AND MODEL ARCHTYPES

Compiled and introduced by Cindy Warwick and Tom Downing, SEI Oxford Office with Contributions from FIRMA project members

3.1 Introduction

The original plan of work for the FIRMA project envisioned common scenarios and a "core model" which would be deployed in different versions for the five regional applications. However it quickly became clear that this was inappropriate. Rather than trying to 'force' the problems in the five regions into a single model and single framing of the diverse issues (which would be bad science and even worse management), we sought to develop unique solutions to the individual problems. This change in emphasis can be seen as a direct result of the commitment of the FIRMA partners to the participation of the relevant stakeholders – faced with a choice of relevance to the problems and challenges presented by the stakeholders and adherence to an academic goal of abstraction, we chose the former. The case-study approach has repercussions for both the choice of scenarios and models.

Subsequently, this report focuses on the comparison of the five regional applications along common lines. This section, specifically, looks at the use of reference scenarios and the applicability of different model archetypes to the regional problems and participatory processes. Work on model archtypes builds on the paper by Moss et al (2001).

3.2 Scenarios: A Common Element

In the most basic form, a scenario can be defined as a postulated sequence of future events. Porter (1985) takes the definition a step further as 'an internally consistent view of what the future might turn out to be – not a forecast, but one possible future outcome'. Ringland (1997) defines scenario planning as 'that part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future'. This section explores how scenarios, using specific and broad definitions, of the term have been used in ABM exercises within the FIRMA project to develop models, to frame modelling and to present model results.

Between the five case study applications, four perspectives on scenario generation and use were identified:

- scenario creation using ABM;
- classifying and controlling uncertainty in ABM;
- eliciting stakeholder perspectives for ABM input; and
- providing consistent settings for model development and testing

These uses are discussed in more detail, on a project-wide basis, in the subsections below. Reports for the individual case studies can be found in Appendix A2.

3.2.1 Scenario Creation Using ABM

In most traditional scenario exercises, scenario creation is driven either by a forward projection from the present or a 'backcast' from a possible future state. In both cases, trends (though not necessarily business as usual trends) or guiding forces fix behaviours and/or outcomes to meet a specific end with little-to-no consideration of how those changes come about or how people will adapt or react against the trends to moderate the overall direction or outcome for society.

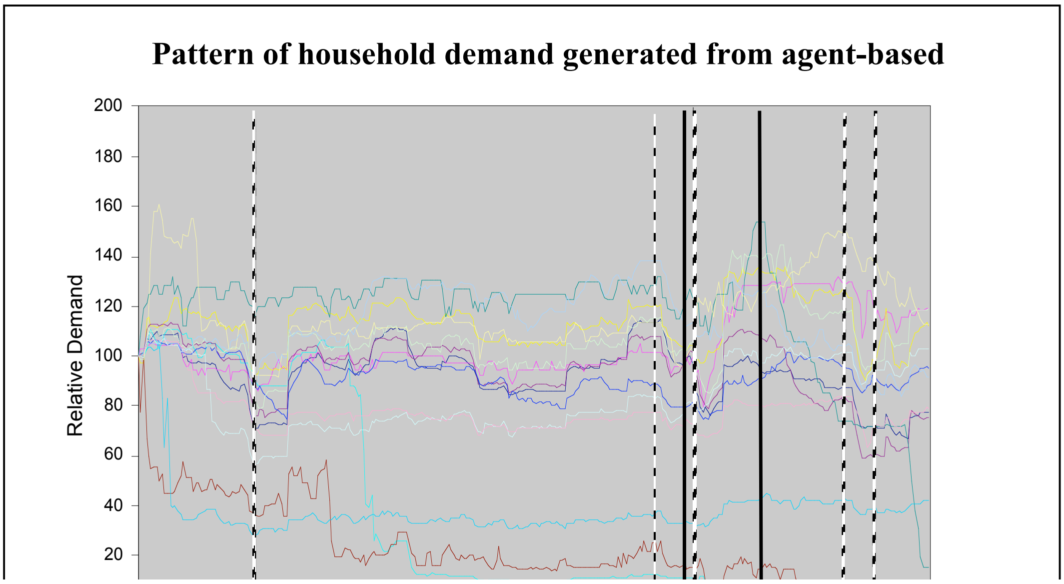
Agent-based approaches, however, take behaviours as the starting point and look at how these behaviours build different scenarios (possibly within the context of a framing scenario, as discussed below). Behaviours can be unique to an agent, or a type of agent, or be universal. In the case of type based or universal behaviours, rules for action will be the same for each agent but their implementation will depend on the individual characteristics or circumstances of the agent. Simulation or gaming agents are able to interact with each other and their surroundings over time and can change in response to this situation. Instead of locking agents into a positive or negative stereotype, agents are relatively free to determine their own outcomes. It is this ability of agents to change their behaviour in response to circumstance that makes ABM a useful tool in the exploration of adaptation. Understanding the triggers and levers of change is possibly more constructive than the unexplained assumption that a certain course of events will naturally follow in a chain of events and reactions.

In the examination of agent-generated scenarios, it can be seen that it is not solely the outcomes that are of interest but the behaviours that generate the outcomes. In a computer model, once the agent behaviours are validated against indicators in known scenarios, the behaviours can be applied to different scenarios to understand possible agent responses and adaptations and outcomes in different situations. In a gaming situation, understanding the perspectives, goals and behaviours of the other agents in an uncertain future is the key component of social learning.

In all of the case studies, agent perspectives and/or behaviours were used to create scenarios that showed system strengths and weaknesses and helped stakeholders to learn about the target system. An example of agent-created demand scenario is shown relative to a traditional demand scenario in **Figure 3.2.1**.

3.2.2 Classifying and Controlling Uncertainty

Scenarios can be effective in controlling uncertainty in planning by defining system extremes or to test the resilience of a plan against different circumstances. If selected aspects of uncertainty are managed it can allow more effective exploration of key responsive or adaptive behaviours. For example, scenarios of climate change can be used to address uncertainty in climate futures. ABM methods can then focus on how behaviours and strategies will work within the different potential climate futures without having to address climate as an uncertainty within the simulation. Socio-economic scenarios can also be used to control uncertainties outside the realm of the behaviours or impacts that are the focus of the study. In this case, socio-economic scenarios can be built with stakeholders, adopted from other scenario exercises or developed by the research team to incorporate situations and parameters of particular relevance to the area of interest.



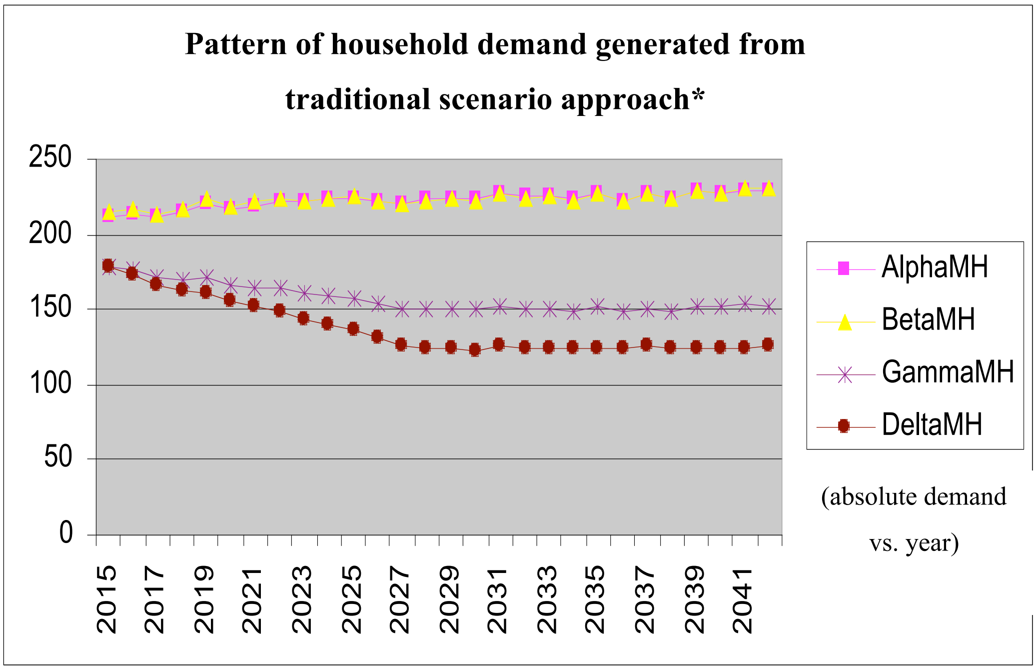


Figure 3.2.1: *A comparison of demand patterns generated through agent-based and traditional scenario approaches*

*scenario approach shows Environment Agency water resources strategies scenarios (EA 2001a &2001b), adjusted for climate change (Downing et al 2003)

In all of the FIRMA case studies it can be seen that scenarios were used to frame the agent-based simulation or gaming exercises. These 'framing' scenarios were taken from widely-accepted scenario programmes (as per Thames Region) or developed with stakeholders (as per Barcelona).

Framing scenarios were generally used to set initial conditions or driving forces in the ABM. These scenario conditions then impacted the starting point and or development of agent activities. In examining the behaviours and outcomes in the ABM scenario, it is important to look for inconsistencies between the framing scenario(s) and the scenario generated through the ABM to ensure that behaviours exhibited and outcomes reached are not in conflict with assumptions made in the creation of the framing scenarios.

3.2.3 Eliciting Stakeholder Perspectives

The building and discussion of future scenarios can also be a way to elicit information from stakeholders. In Zurich case study, scenario building was a way to discuss the implications of different options available in system management. In the Maaswerken case study, stakeholders provided scenarios for future riverbasin development and also their perspectives in evaluating the management plans presented by other stakeholders. In Barcelona, a scenario building process was used to discuss the likelihood of possible futures for the selection of an appropriate framing scenario for simulation activities.

In the FIRMA case studies, scenario building generally was not used as a creative process to build a common vision but to elicit specific information and perspectives for ABM development. In the Barcelona case, a range of likely futures were sought while in the Maaswerken case the goal was to identify the unique plans and perspectives of the different stakeholders. The Zurich approach worked to show areas of consensus and contradiction highlighting areas of uncertainty within the system.

3.2.4 Model Testing

In the Orb case study, scenarios were used for the testing and development of modelling techniques. In one application, a common scenario was simulated by different models at different scales. The common scenario between models allowed for the investigation of differences in outcomes due solely to modelling technique. In a second application (SCICOPTER) a scenario was used for model testing to ensure that the simulation techniques and capabilities were appropriate for use with stakeholders in a real setting.

3.3 Model Archetypes: Criteria For Comparison

To achieve robust insight, the modelling must be appropriate to the policy issue. It is almost never the case that a single model will be adequate for all issues. Conversely, it is often the case that models are inappropriately applied to policy issues for which the design and structure are not adequate. And all too often, the structural suitability of different model types is hidden from the policy maker. Formal methods for the inter-comparison of models have been established in some disciplines (e.g., the NUSAP approach) and undertaken for some applications (e.g., global dynamic vegetation models). Less common is guidance on the choice of models from the range of traditions that might be suitable for a specific problem domain.

Table 3.3.1 gives eleven aspects of integrated assessment modelling that are often cited as essential conditions of application. The table also provides an initial assessment of these conditions for participatory ABM, although there are few examples of such work to verify the proposed methods. The table implies a qualitative comparison with dynamic simulation models, which are common in adaptive resource management. However, the goal of the table is to highlight the different strengths of the two modelling approaches and discuss conditions in which one method might be preferable to another. A strength of the FIRMA project, however, is that it has not just looked at ABM alone but, in some case studies, has worked to combine elements of dynamic and agent-based programming to gain the advantages of both approaches. Representing the fields with two idealised examples in **Table 3.1.1** is intended to highlight the relevant conditions of applications and not to infer a critique of individual models. Many of the conditions of application are fundamental challenges to all policy modelling.

Table3.3.1. *Conditions of application for integrated assessment modelling*

Condition	Description	Dynamic simulation, sustainability models	Participatory agent-based simulation
Model representations			
Natural systems	Link to physical and biological models	Common, intermediate complexity, reduced forms models	Agents manage the environment and react to environmental changes
Social agents	Number of agents	Not usually explicit although groups of actors may be part of a sub-model	Multiple agents, inheritance of characteristics from group classes
Agent motivation	Conceptual model of agents, social theory	Not explicit; optimising or satisficing	Can test social theory, often bounded rationality
Societal structure	Relationships between agents or sectors; socio-economic change	Dynamic, related to external driving forces or macro-level relationships	Structure can evolve in response to agent "rules, norms and strategies"
Technology	Role of innovation and diffusion	Learning curves, bottom-up best available practice	Behavioural effects on technology
Resolution and scaling	Geographic and temporal resolution; scaling	Single scale with geographic layer (e.g., 0.5°)	Scales from fine grained through representation of stakeholders
Validation	Model comparison against observed reality	Calibrated against historical time series of major trends	Observed processes; scaled up behaviour at higher resolution
Use/policy context			
Stakeholder participation	Model facilitates stakeholder participation	Requires expert knowledge to judge validity	Facilitates engagement by evaluating agent rules
Hypothesis testing	Mode of model insight and approach to uncertainty	Comparative statics; baseline assumptions critical; uncertainty limited by complexity of model	Structural change and pathways of decision nodes; uncertainty in physical/social interactions, limited by complexity of model
Verification	Robust policy insight; cost-efficiency; reputation through peer review	Short-term decision making, unlikely to be verifiable for long-run changes; compared to more detailed models	Difficult to gauge until more experience is gained
Transparency	Access to assumptions that influence model results	Possible to signal most important influences through sensitivity testing; large number of assumptions mask critical structural issues	Difficult to gauge until more experience is gained

In this report, we use the conditions of application for integrated assessment modelling as a framework for comparing the ABM approaches undertaken in the different FIRMA case studies. The categorisation is then used to explore the achievements and outstanding challenges of ABM application in the project. **Table 3.2.2** presents a sample description of the AMB approach in the Thames case study. Details of all case study applications can be found in Appendix A3.

Table 3.3.2. *Example for the Thames case study*

Condition	Description	Participatory agent-based simulation
Model representations		
Natural systems	Link to physical and biological models	Agents do not see the environment but react to a policy agent that communicates drought risk and recommended water use
Social agents	Number of agents	100 agents sampled according to household size, ownership of water using appliances (based on company data), agents are located on grid (random distribution)
Agent motivation	Conceptual model of agents, social theory	Relative influence of their own demand for water, of policy agent's recommendation and of water usage by neighbours
Societal structure	Relationships between agents or sectors; socio-economic change	Behaviour changes over time in response to aggregated endorsements of water saving messages, but no structural social change
Technology	Role of innovation and diffusion	Water saving technology is introduced at various times, exogenous to agents' (i.e., no demand per se for technology)
Resolution and scaling	Geographic and temporal resolution; scaling	Model represents a sample of a water company region, which might have several million customers; while agents are placed on a grid, it does not correspond to an explicit spatial resolution—agents can 'see' neighbours in adjacent cells
Validation	Model comparison against observed reality	Behaviour of the model population corresponds to observed profiles of demand management, but data are lacking for finer-scale validation
Use/policy context		
Stakeholder participation	Model facilitates stakeholder participation	Stakeholders have reviewed the model but not the detailed behavioural assumption (e.g., wealthy households adoption of power showers); model will underpin drought contingency role playing in the project
Hypothesis testing	Mode of model insight and approach to uncertainty	The main insight has been to show that a wide variety of profiles of water demand are plausible, and particularly so with climate change—assumptions about behaviour are essential for demand management
Verification	Robust policy insight; cost-efficiency; reputation through peer review	A formal evaluation has not been conducted--results are being reviewed by stakeholders at present
Transparency	Access to assumptions that influence model results	While assumptions are explicit and easy to report, it is less clear that stakeholders understand their implications—particularly since the model is likely to be their first exposure to agent-based social simulation

From the detail in the tables, we note five salient conclusions.

First, to seek to formulate optimal policy over a long time period and diverse socio-geo-political contexts may be dangerous. The role of modelling should be to test plausible outcomes from different strategies. Such strategies should include learning and monitoring.

Second, models based on presumed theories of behaviour are problematic. A comprehensive social science does not exist, on the scale of allowing us to predict behaviour over the course of the next decade let alone the century time scale of climate change.

Third, the representation of social agents is critical to understanding diverse pathways. Models, like decision makers, should focus on decision nodes and pathways, informed by alternative social theories (including conflict and negotiation as major elements of global change policy).

Fourth, policy strategies should be set in the context of diverse futures, the full range of scenarios of socio-economic change, environmental conditions, societal values and governance. The goal of robust insight requires full evaluation of the fundamental structures of society. Technology will certainly change the future, but only in combination with social norms, economic values and political power.

Fifth, realism—encompassing validation and verification—is essential to engaging stakeholders in meaningful analysis of ABMs. Models should provide features that are recognisable in reality, correspond to stakeholder mental models, and are verifiable against observed data.

3.3.1 The FIRMA models: alternative archetypes

Tables in Appendix A3 suggest how the FIRMA models correspond to the conditions of application. In the case of modelling for the Thames region, the project focussed on a relatively narrow set of issues related to water demand management. A comparison of a dynamic simulation model and an agent-based approach highlighted the crucial role of behavioural responses to water scarcity, policy regulation and technology. In fact, the outcome of climate change may be at least some households consuming far less water as they shift to water-saving devices (e.g., low flow showers and trickle irrigation of gardens). In terms of planning water resources over the next twenty years, understanding such a diversity of outcomes is essential.

The Barcelona case is similar—initially developed in the same language (SDML) and with a focus on the social construction of demand. However, in the Barcelona case the emphasis, driven by the stakeholder identification of the problem, is on migration (households do not move across the Thames grid) and regional total water demand (rather than individual households). More agents are modelled (10x the Thames case) and they respond to more environmental signals (only drought messages in the Thames model). However, in both models, technological innovation is exogenous—and relatively less important in the Barcelona case.

Household water consumption is also a focus of work conducted in the Orb case study to compare ABM and aggregate modelling. In the agent-based work the number of agents is similar to that used in the Barcelona study. Agents can react to the state of the physical system and the activities of their neighbours. The study found that the aggregate model was usually sufficient in its calculations of demand though it sometimes failed to capture the complexity of the agent interaction.

The second model in the Orb case study, the Phylou model, also has agents interacting with the natural world, but in this case the physical world is specified spatially and topographically with land cover, plot sizes, and topography. Climate is used to drive the dynamic aspects of the system, including pesticide run-off. The model is developed and runs as part of a participatory process to explore cop management options for the Orb Valley.

In the Maaswerken case study, effort was directed towards combining the ABM and dynamic modelling approaches to make use of the advantages of both. The natural system is represented by a dynamic model; however, the model is used as a forum for discussing system uncertainties and the beliefs and goals of the stakeholders involved in river management. This approach focuses on working with a small number of highly complex agents as opposed to a large number of simpler ones, as per the households used in Thames and Barcelona.

In the Zurich case study, includes many of the attributes, mentioned in the other case studies: small number (8) of complex agents; technology diffusion for the calculation of demand; and an indirect impact on a select set of environmental indicators. However, these aspects of ABM were developed in a participative way that included knowledge elicitation, the development of a simulation model and a role playing game. The role playing game allowed stakeholders to view the complexities of the management system as a whole to generate insight and highlight system linkages.

3.4 Conclusion

It may be useful to think of the uses of ABM in three ways. Common to all of the regional applications is the use of ABMs as a way of organising and understanding the set of issues of concern to stakeholders. The interactive and iterative process of identifying the key actors, their decision structures (e.g., objectives, motivations, lines of evidence, planning horizons and conditions) and interactions with each other is necessary for designing an ABM. But it also has benefits in terms of seeking innovative solutions. The participatory process seems to have led to development of models with greater focus than is often the case in modelling complex socio-environmental issues. The Zurich approach—from board games to internet models—typifies this process of structuring the stakeholder-expert interactions.
The second mode of ABM then is to focus on specific interactions that are critical to understanding the problems identified by stakeholders. For instance, in the southern England study, the broad problem concerns the dynamic management of risk in the water supply/demand balance. However, the behaviour of households had received less satisfactory treatment in the industry and yet was the greatest source of uncertainty. So the ABM focused on several discrete modes of behaviour regarding drought responses, regulation and technology.

The third mode is to use ABM as the overall technique in more elaborate integrated assessments. The Cemagref approach is a good example. In general, the constraints of computer processing limit the number and/or cognition of agents in regional modelling of this sort. However, it facilitates the involvement of regional stakeholders in seeking system-wide solutions to management problems.

In the FIRMA project, scenarios are a key aspect of all three modes. As inputs scenarios have been effective tools in model testing and constraining the model to focus on areas of interest. As outputs, scenarios have provided a tool for validation of behaviours incorporated in the ABM and a means of discussing the implications of behaviours for potential futures. Along the way, scenarios have also provided a forum for dialogue concerning system uncertainty and available options.

Scenarios used and produced have varied greatly by case study considering the issues of interest to the locality and the role of scenario use in the ABM programme. Though the scenarios themselves are generally of interest, in some cases they are secondary to the social learning generated through their creation and the improved understanding of behavioural practices and patterns.

The FIRMA project has achieved considerable progress among the regional applications in:

- Representing and linking ABM to natural systems
- Constructing social agents at different levels of cognition
- Adoption of technology, once introduced; however we did not explore endogenous technological development
- Spatial and temporal resolution seemed an important issue at the outset but seemed to have been resolved satisfactorily for each regional application
- Validation was explored in several ways, including correspondence of the statistical signatures from observed and modelled data.
- Stakeholder participation was undertaken in each project, in different ways.
- Hypothesis testing was achieved in comparisons of model runs.
- Verification of the robustness of the model-derived insight is ongoing; while some progress was made, more formal tests of the benefits to decision making should be pursued.

Among the attributes of ABM that remain as significant challenges, we note:

- Representing agent motivation—no single theory or implementation of cognition or planning was clearly superior and further innovation is required
- Including social structures and the dynamics of social change—in particular negotiations between agents can be represented in simple ways, using existing options and scenarios, but requires further research to resolve multi-party processes.

- Scaling up from cognitive agents (fine grain) to systems behaviour (with many more, coarse grained agents) was not tested and remains a conceptual and practical challenge.
- Transparency was facilitated through user interfaces, however we did not seek to test the ability of stakeholders to assimilate the model behaviour .

3.5 References

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SECTION 4. KEY POLICY MESSAGES

Compiled and introduced by Cindy Warwick and Tom Downing, SEI Oxford Office with Contributions from FIRMA project members

4.1 Introduction

In general, the findings of the FIRMA project have stressed the importance of a case-study specific, participative approach to agent based modelling (ABM). As a result, the policy relevance of each case study is very specifically targeted to issues in each case study local. However, the goal of this section is to look beyond individual findings to discuss policy issues that have resonance across case studies. The policy messages are informed by the different methodological approaches to ABM and different regions where the methodologies were applied. The project has formulated key messages on three topics: water demand (Section 4.2), approaches to risk (Section 4.3) and conflict and consensus in water management (Section 4.4). The key messages are presented as part of the WP5 report but are intended to be useful as extractable, stand-alone documents.

4.2 Key Message: Water Demand

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David Saurí, Mercè Capellades and Mònica Rivera, Universitat Autonoma de Barcelona

4.2.1 Introduction

This paper will discuss the methods, lessons learnt, findings and application of agent-based modelling (ABM) work on household demand modelling in the FIRMA project. The paper will focus on case studies conducted in the Thames and Barcelona regions where household water demand was a main project focus.

In general, the paper aims to show that an agent-based approach will yield a richer base for policy making than using statistical forecasts alone and that an agent-based approach allows you to involve stakeholders in the development of the model to encourage learning about the systems and other stakeholders involved. However, the effects of water policy implementation differ according to context and history, therefore, the paper will also aim to show that it is not possible to have one model that is applicable for all contexts.

4.2.2 Background On Demand Planning & Management

In the past, the maintenance of public water supply has been focused predominantly on the securing of adequate supply to meet projections of increasing demand from households, agriculture and industry. However with increasing competition for available water resources (including the acknowledgement of the rights of the environment to adequate supply) and decreasing security of supply due to climate change, water managers are increasingly looking towards the planning and management of demand to meet the supply-demand balance. Demand planning, beyond business-as-usual trend projection is being undertaken in an effort to eliminate problems of under and over supply as lifestyles and public behaviours change with the times. Demand management goes a step further in seeing how this demand can be changed (usually reduced) to increase security of supply with minimum expenditure.

This paper specifically deals with the issue of household demand as opposed to demand by industry, agricultural or other water users.

In the UK, the focus on drought occurrence and drought risk has come about due to the varying climate and hydrological conditions in the region as well as recognition by regulatory agencies of the need to incorporate demand management into resource management to meet the supply-demand balance in a more sustainable manner.

Water planning and management in the Metropolitan Region of Barcelona (MRB) needs to address the unstable equilibrium between water supply and water demand that has risen during the last decades. This equilibrium is threatened by the highly variable precipitation patterns characteristic of the Mediterranean climate that may prompt emergency situations (four drought alerts issued in the 1990s) and eventually produce restrictions in domestic water supply. An important factor in aggravating in-balances between water supply and demand is the change in the urban form leading towards a growth in single houses and condominiums (often with gardens and swimming pools) that boost domestic water demand in the periphery of the region.

4.2.3 ABM Approach

In the case studies it can be seen that the uncertainty related to water supply and demand are being increasingly recognised in water resources planning. However, awareness of the problem has not necessarily lead to adequate solutions. Trend projection is still a key aspect of resource planning, though under new planning regimes or regulation, the trends being projected may have changed and may consider more factors. Scenario and trend-based approaches are useful for strategy testing, however they give little-to-no insight concerning how or why individual behaviours do, or do not propagate certain scenario trends and therefore how these trends can best be managed or redirected.

In the Thames and Barcelona case studies, the ABM approach is used to understand how and why households are using water, possible results of these water-demand behaviours in differing situations and the potential impacts of behavioural changes.
In both case studies, agents, characterised by selected parameters, follow rules for water consumption considering their characteristics and their situation with respect to appliances and housing. Through communication with a user-generated number of other, similar, agents or an overarching policy agent, the household agent can learn

about new situations or behaviours. Different actions will be 'endorsed' by different agents and the sum of the endorsements, considering the agent's memory for past actions and the weighting that the agent applies to the different endorsement inputs, will work to decide how the agent behaves in future iterations of the simulation. The 'copying' of behaviours 'endorsed' by other sources has been described by Cohen (1985) and has been previously implemented in agent-based approaches (see Moss and Sent, 1999; Moss, 1998) to capture observed behaviour. It is anticipated that these behavioural insights will lead to insights pertinent to demand planning and management.

Agent structures differ in the two case study models but both contain modules representing climate, physical systems, consumer/household behaviour and policy agents. These modules and their agents can communicate with each other, changing their preferences and surroundings against the backdrop of changing climate and regulatory futures.

4.2.4 Participation

In both case studies a stakeholder platform was used to validate behavioural rules and results with respect to their experience in the water industry. The stakeholder platform was also key in providing quantitative data regarding previous patterns of water consumption events and, in the case of Barcelona, provided input and evaluation for the scenario building that formed a framework for the study.

The participation of stakeholders has proven to be an important challenge. Stakeholder fatigue and little-to-no previous experience in the creation of stakeholders platforms for complex socio-environmental issues sometimes mad it difficult to convince stakeholders to become involved in the project. The scope of the models also meant that it was difficult to foster participation with all the agents represented in the model. For the most part, this meant that participation was restricted primarily to water experts who could validate the behaviour of policy agents and also had expert knowledge regarding the type of individual, household or aggregate behaviour expected in response to policy implementation.

The agent-approached helped stakeholders to understand how and why the future will deviate from, or support, projected scenarios and how they could work to manage demand towards a particular scenario considering individual household behaviour.

4.2.5 Outcomes And Applications

4.2.5.1 Thames Case Study

The agent-based model revealed that an increased frequency of drought could provide the catalyst for the adoption of water saving technologies and associated reductions in demand, or alternatively if the presumption of entitlement to a private good were to exceed the willingness to conserve water during periods of drought, increased frequency of drought could lead to consumers increasing their demand beyond the high reference scenarios. Critically, the model identifies the importance of community interaction and particularly the mimicking of neighbour behaviour as a key determinant of the uptake of new water saving technologies. Neighbourly interaction also determines the extent to which households are influenced by policy agent exhortations to use less water in times of drought – closely knit communities appear to be less impressionable. The findings, although purely qualitative, suggest key social determinants of future water demand

A possible application for the model is projecting and following up on the successes, or failures, of direct marketing campaigns. This would focus on the impact of targeting key households for new technology or policy messages. The impact that this would have on neighbourhood consumption could be projected and then monitored.

4.2.5.2 Barcelona Case Study

Results of the simulation model based in agents are presented according to the three scenarios developed in the participation process. Each scenario foresees two types of climatic states: a “normal” state (that is, no substantial changes in temperature and precipitation trends), and an “extreme” state (changes in temperature and precipitation leading to droughts). Scenario “A” (the more plausible according to our stakeholder platform) considers a continuation in the trend of residential mobility, from the compact to the diffuse city, and introduces water conservation measures. In this scenario, water supply is insufficient to absorb demand despite conservation. However, in "normal" climatic situations, emergency levels are not reached. Only in periods of drought, some action in the form of enhancing water supplies is required. Scenario "B" maintains residential mobility trends this time however without water conservation measures. Simulation indicates the rapid rise of emergency situations that can only be solved through a substantial increase in water supply such a large scale transfer from the Ebro or Rhone rivers. Finally, scenario "C" introduces changes in residential mobility (migratory fluxes towards the diffuse city diminish) without water conservation measures. In this case, emergency situation are not reached even under conditions of climatic stress.

4.2.6 Summary

In both case studies it can be seen that the AMB approach allowed researchers to look at the bottom-up detail of possible futures, as opposed to the broad planning perspectives and assumptions taken by government. In the Thames case study, ABM was used to question scenario assumptions about behavioural changes through an examination of behaviours in response to climate stress. In the Barcelona case study, the ABM process was used to identify possible growth scenarios and modelling was applied to examine the possible quantitative impacts of scenario realisation on water demand volumes. In both cases, the ABM approached flagged weaknesses in the conventional, top-down assessment of demand futures. The models highlight factors that will need to be considered or controlled in attempting to realise a planned future in water management.

The case studies highlighted the importance of working with stakeholders but also acknowledged that it was not always easy to convince stakeholders of the value of new research and participation methods. The size and scope of the project also proved difficult as the incorporation of many different types of agents usually meant that not all agent types were represented in the stakeholder group. Where stakeholders did participate, the modelling assumptions and outcomes could be validated against their expert opinion and models served to educate stakeholders about system links and behavioural issues relevant to planning.

In both cases, the development and application of agent-based models is limited by validation data. In the case of water demand, there are no long-term records of demand for individual households for daily or monthly intervals. To effectively validate household behaviour at an individual household level, consumption data along with interview or survey data would be required. Community interaction is also difficult to understand as consumption surveys are usually spread over a large area, as opposed to focussing on one neighbourhood. Models were therefore validated using aggregate demand data sets to observe similar patterns of behaviour, if not individual behaviours themselves.

A second limitation to the modelling was computer time, initially both models were programmed in SDML which, though a flexible and innovative programming environment, proved to be cumbersome in memory and runtime. The number of agents and the behaviours available to them had to be developed considering the practical limitations of available computing systems. Currently, run time and memory limitations are being overcome by converting the programmes to a JAVA platform, though this loses some of SDML's functionality.

These limitations in validation data and system capacity are some of the reasons why an overarching model was not developed between the different case studies in the FIRMA project. The models deal with individual behaviour that would have to be initialised and validated in every different cultural application – this data is more likely to be available (in some form) in areas where the issues being examined have been identified (by stakeholders) to be of concern). Also, added features (applicable to one case study region but not necessarily another) would serve to make the programme less user friendly, less transparent and more cumbersome to run.

In both cases, however, ABM was used to build a system of social interaction that reacted to environmental and policy drivers. Behaviours and technologies (through purchase or by change of housing stock) were diffused through the social system against this socio-environmental backdrop creating possible patterns of consumption and policy responses to be considered in the future planning and management of water demand.

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4.3 Key Message: Risk

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4.3.1 Introduction

This paper will discuss the methods, lessons learnt, findings and application of agent-based modelling (ABM) work on the understanding of risk and adaptation to risk in the FIRMA project. The paper will focus on case studies conducted in the Thames and Maaswerken regions where risk of climate hazards were examined as part of the FIRMA project.

This paper aims to show that an agent-based approach yields a rich base for policy making than traditional approaches to risk alone. In general, the comparison of the two case studies shows the importance of the multi-stakeholder paradigm and allows us to look at other modelling methods in new ways (shown best in Maaswerken). The multi-agent paradigm also allows us to capture the sometimes illogical behaviour (as per the hydro-illogical cycle) of event response - the social construction of risk (shown best in Thames). An agent-based model allows you to involve stakeholders in the development of the model to encourage learning about the systems and other stakeholders involved. However, the effects of water policy implementation differ according to context and history, therefore, the paper will also aim to show that it is not possible, or desirable, to have one model that is applicable for all contexts.

4.3.2 Traditional Approaches To Risk

Risk now occupies a central place in thinking about contemporary society. The work of the social theorists Beck (1992) and Giddens (1999), who argue that contemporary society is better understood in terms of risk rather than for example class, has helped give risk its central place in much contemporary intellectual debate. The concept also increasingly occupies a key position in policy terms.

Considerable efforts are made to control, reduce or eliminate much identified uncertainty. Inevitably much of the risk cannot be eliminated for reasons of cost, the limits of knowledge, and factors inherent in humans and their institutions. We term this residual risk. People make provisions for residual risk either psychologically (through denial or fatalism) or through insurance and contingency planning.

A perennial problem in risk related policy is that perceptions of the costs and benefits of different risks often varies greatly between stakeholders. The formal institutions of government, science and the corporate world, tend to place more emphasis on aspects of risk which lend themselves to the standard tools of analysis and measurement, in particular probability statements (see for example Finkel and Golding, 1995). These are convenient and enable the risk to be incorporated easily into economic and other calculations. However, the probabilistic approach may ignore important aspects of the residual risk, and may be misleading if key elements or parameters of the risk are overlooked (on this latter point see Bier, 1999).

Four characteristics of traditional modelling approaches to risk and uncertainty can be generalised as follows:

1. Prediction. Most mechanistic modelling perspectives seek to predict the behaviour of some target systems. For example, the ultimate goal of global climate models is to predict the long-run evolution of the atmosphere and its response to increased greenhouse gas concentrations. Systems dynamics models are the prevalent tool in predictive models.
2. Optimisation. Policy evaluation models almost always recommend one decision or course of action as better than another. By evaluating a range of options against specified criteria and values, methods such as econometric or linear programming models, provide ‘solutions’.
3. Parameter uncertainty. Stochastic approaches estimate the uncertainty (or probability of different outcomes) based on ranges of values for the parameters in the model. The ranges may come from expert opinion or observed relationships, or are simply plausible boundaries.
4. Expert system. Most models are constructed to encapture the expertise of some discipline or topic. For instance, groundwater models might include the state-of-the-art in surface infiltration and sub-surface flow based on experiments and analyses in geophysics and hydraulics, among other disciplines.

These modelling characteristics and their application to problem-solving are clearly over-simplified but work to highlight how traditional approaches are ill suited to the complex character of hydrological risk. In applying traditional approaches, the target system is perceived as a machine to be controlled rationally, reducing destabilising pressures and maintaining equilibrium. However, the complex relationships between competing pressures, the need to evaluate economic, social and ecological factors, and the ability of agents (social or biological) to adapt to changes in their environment contribute to deep uncertainty. Most applications assume a single decision maker, or a 'global commoner' that does not learn from observations about how the real world actually behaves. Traditional approaches embedded in a single discipline, ignorance of many critical interactions, and reliability only for short time frames and confined geographical domains are inadequate. However, not only is there a paucity of adequate data, but the phenomena and process are themselves not fully understood (van Asselt and Rotmans, 1996)

The challenge of understanding hydrological risk management requires several levels of integration: natural and social dimensions; risk (including drought and floods) across the environment; individual, corporate and institutional behaviour; and technical expertise among decision makers and stakeholders. Complexity stems from the number of relationships; uncertainty from the many altered states of the future.

4.3.3. The ABM Approach

ABMs are not generally predictive tools, rather they become mechanisms by which behaviours and their possible consequences can be explored. The use of models is to explore the nature of problems, examine the viewpoints of different actors and their inter-relationships and to discuss the impacts of different behaviours on other actors and on the system over time.

Agent-based modelling can be seen as a tool and mode of discourse rather than a means to monitor, predict and provide. ABMs hold promise for realistic representations of observed behaviour. Artificial intelligence and multi-agent systems have been employed to investigate a range of social interactions (Gilbert and Troitzsch, 1999).

In the field of water resources management, institutional factors are likely to be at least as important as economic, technical or physical considerations in developing and implementing effective policies (Ingram et al., 1984). For example, risks associated with hydrological events are affected by both the nature of the hazard (duration, type etc.) and the institutional structures established to manage such hazards, which in many cases are likely to be a consequence of how preceding significant hazards were managed.

Changing structures, of the environment, regulatory regimes, stakeholder positions, consumer preferences, for example, require evolutionary approaches (as distinct from those based on optimisation). The path-dependent nature of evolution and its sensitivity to perturbations mean optimal system efficiency or performance can not be guaranteed. In addition, path dependence can induce 'lock-in' where the outcome may be 'survival of the first rather than survival of the fittest' (Arthur, 1988). Furthermore, evolution can indicate multiple equilibria (Arthur, 1988; Costanza, 1996).

4.3.4 FIRMA Case Studies

In the FIRMA project, ABMs have been used to examine issues and behaviours around flood and drought risk in two case studies. The Thames region case study has examined issues related to drought management and the Maaswerken case study has focussed on river management strategies and flood risk.

In the Thames region, a role-play game is being developed in order to better understand the agent behaviours, perspectives and motivations in the new system of drought planning implemented in England and Wales. Though the drought plans developed by the privatised water companies and the environmental regulator contained detailed information on procedures and options for drought management, they contained little-to-no information on the objectives in drought management and how supply/demand options would be selected to best meet these objectives. The game was set to enact a 'virtual drought' (U.S. Army Corps of Engineers, 1994) to make decision-making more transparent and open to discussion. The virtual drought would also work to test the appropriateness of objectives and management strategies considering the objectives and strategies of other decision-makers and system uncertainty.

A gaming approach was taken to this topic as a first step in developing a agent-based simulation model. A game was needed to gather more information about decision-making in practice before a game could be programmed. Most problematic in programming was how to manage negotiated plans. In addition to information collection, gaming is a chance for social learning between actors in drought management. Due to a recent reorganisation of staff at environmental regulator and changes that have occurred in the water companies since the last drought, the game will enable the new decision-makers to interact and understand the uncertainties, personalities and perspectives in management before a hazard event occurs.

In the Maaswerken case study, river management stakeholders were interviewed to determine their perspectives on system parameters and their objectives in management. Flood risk was one consideration in the formulation of a management regime.

A comparison of the two case studies shows that the problems and perspectives being encountered are quite different in general and in detail. The Thames case study focuses on drought management as an ongoing process of negotiated management to meet long-term goals and overcome short-term hazards. The Maaswerken study focuses on the multi-stakeholder creation of a management plan. The case studies are based on topical issues in the study areas. Even where problems could be found in common, the specific numbers, types and viewpoints of stakeholders involved would be situationally dependent. In looking closely at the issue of negotiation, which was problematic in both cases, it can also be seen that different histories and cultures of decision-making in the two countries lead to problems in cross-applying any behavioural models developed.

The two case studies also differed significantly in their approach to time. The Thames case study looked at long-term management and adaptation as driven by climate change. The Maaswerken case study, however, looked at a present issue, and projected viewpoints of different agents to create possible scenarios of impacts that could be judged relative to stakeholder’s evaluation criteria.

In common, however, the case studies have worked with stakeholders to identify different system assumptions and examine the impacts of these assumptions on their relationship between stakeholders in decision-making. In both cases a small number of complex stakeholders were considered, as opposed to a large population of simple agents, common to many applications of agent-based modelling.

4.3.5 Summary

Models that use statistical forecasts of event size and recurrence are an important part of hazard management. However, they do not tell us anything about how these risks, and the systems in which they are generated, are interpreted by the different stakeholders involved. Interpretations of risk and objectives in management will be the critical hinge in decision-making in any process that is not totally automated. Due to the many possible interpretations of risk and assessments of possible hazard impact to the system, risk cannot be taken as a well-defined subject for objective consideration and it must be represented subjectively from each stakeholder's perspective.

Stakeholder involvement was key to defining parameters in the modelling/gaming and taking an agent-based approach allows representation of the different assumptions used by the different agents to identify solutions that can be suitable within various paradigms and most resilient to different system risks. In a good ABM process, learning is not restricted to the research team but is a platform for stakeholders to consider their own objectives and to learn about the perspectives of other stakeholder in the system.

The complexity of the stakeholders and issues involved was problematic in that a comprehensive approach to simulation of agent negotiation was a significant challenge to the project. To work around this issue, case study work in the Maaswerken region focussed on characterising agent perspectives on system parameters and management goals and therefore understanding stakeholder perspectives in negotiation. The Thames region case study moved away from computer simulation approaches to build a human laboratory for the observation of real stakeholders interacting in simulated settings.

The case studies show the impacts of different objectives and different beliefs about the system at present and at future lead to conflict in current management situations. However, the agent-based perspective has helped to identify and clarify areas of disagreement by explicitly examining agent beliefs and their implications in a gaming or simulation context.

4.3.6 References

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4.4 Key Message: Conflict and Consensus

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Conflict and consensus among stakeholders occurred several times during the planning phase of the Maaswerken project. We have to distinguish these phenomena on two distinct scales, individual and organisational. A closer look at the participatory process of the Maaswerken project reveals a link between scale levels and types of participation. In the early phase of the project, citizen participation took place with two clear objectives:

1. Stakeholders have to be identified and informed of the goals of this infrastructural project.
2. The role of the stakeholders with reference to their perspectives and interests had to be identified.

Fulfilling these objectives was important for the legitimisation of the stakeholder participation.

During the citizen participation, and in the transition phase between citizen participation and stakeholder participation, citizen organisations formed as a result of the coming together of a number of individuals with local interests. The regional citizen organisations with regional interests are in principle a result of a long consensus process. In fact some specific local interests where forfeited at times in order to give a stronger voice to regional goals in a negotiation process among the various organisations. This process has not been modelled within the FIRMA project since the focus of our investigation was on the negotiation of the main stakeholder organisations. This negotiation process shaped the course of the Maaswerken project. However, it is important to take in account this process of emergence, since this resulted in the establishment of a new stakeholder organisation.

Our modelling approach focuses on the negotiation of stakeholders at the scale of organisations. During our field observations we observed one remarkable example of conflict: In the year 2000, the gravel extractors claimed that they required double the amount of gravel to be extracted for economic reasons. This entailed the dissolution of a consortium of gravel extractors and nature organisations. This apparently incongruous collaboration occurred because the aim of the project was to provide natural habitats within extracted areas.

In the Maastricht case study, conflict and consensus have been represented with the help of the concept of cognitive agents in the agent-based model. Basically, the agent architecture of every agent is a type of symbolic representation. This consists of the two main components, goals and beliefs. Every agent is able to evaluate a planning strategy consisting of a number of measures that change the current environment. The relevant features of the environment are described by the three variables safety (flood probability), costs (cost and benefit of gravel extraction) and natural area. Every agent has threshold values for any of these variables, and also has weights to ascribe priorities to these variables. These threshold values can also be interpreted as individual goals. Conflict is occurring when the value of a variable of one agent is outside the range of other agents. Consensus is reached if the values approach a range within the tolerance levels of negotiating agents.

The observed situation can be easily described in the model by introducing a planning strategy with that specific value. The principle of symbolic representation supports the modeller by identifying a conflict problem during a participatory session. Stakeholder representatives are able to see the consequences of an introduced strategy on the environment and on the other agents. This may serve as an underlying basis for further negotiation and related social learning processes. Another advantage of this approach is the fact that stakeholders are able to observe inter-dependencies of issues/goals in a world of complex problems. Moreover, the stakeholders, represented as agents have the opportunity to introduce their own beliefs. This may be done by modifying cost and hydrological parameters. These modifications result in various outcomes, also indicating underlying uncertainties. The application of symbolic representation serves as an ordering tool, and supports communication among stakeholders and modellers. Moreover, the translation of real-world interests and perspectives into values in a computer program is supported and made transparent.

In conclusion we can say that an agent-based approach cannot answer all the question raised in a complex case study. However, due to the individual properties, agents are capable of representing real world problems from an individual point of views, and can thus help to reveal important contradictions and conflicts as well as uncertainties within complex water resource projects.

APPENDIX 1. USER INTERFACE CASE STUDY REPORTS

A1.1 Barcelona Case Study

A1.1.1 Software Item Identification

Here we describe the user interface design and issues arising for the Drinkable Water Management-Barcelona Region computer model. Further explanation of the model can be found in accompanying work package three (WP3) FIRMA report.

A1.1.2 Intended Users and Functions.

The model has been implemented with two languages. The SDML[1] version has been intended to create the structure and check the results of simulations at low scale. The Java version has been realized with the SDML structure, but a greater scale, close to the real system we are studying, firstly, to facilitate discussion between stakeholders.

The intended users of the software item are any interested investigation group in the topic, policy makers, water companies and in general any interested stakeholder.

The work is a tool for the learning and support to the decision to the policy makers in charge of the water management. The program allows the interaction of the users with the simulation in real time, in order to:

- Test different supply policies, acting on the infrastructures, different demand policies, by means of the use of different price strategies, or mixed combinations of both.
- Analyse different scenarios.
- Analyse different climatic profiles

The simulation gives us a measure of the suitability of each one of the strategies by means of the concept of "social unhappiness" and "expected incomes".

A1.1.3 Design Outline.

The design of the Graphic User Interface of the Java version is based on windows. These windows can be divided in four types depending on their functionality:

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[1] SDML is a simulation language developed at the Centre for Policy Modelling, Manchester. For details see the FIRMA WP3 Report.

- Windows for control of the execution. This window (there is only one) has the general options for the control of execution of the simulation.

Figure A1.1.1: *Window of control of execution of the process*

- Windows for the configuration of the parameters of the simulation.

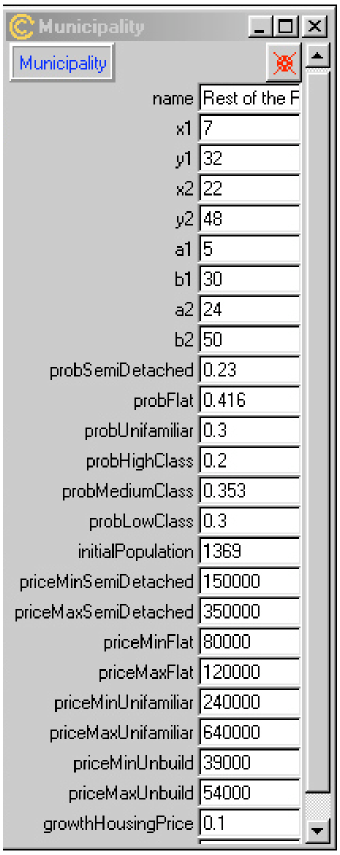


Figure A1.1.2*: Configuration window of a Municipality.*

- Windows to monitor execution of the program. They reflect most of the outstanding information of the model.

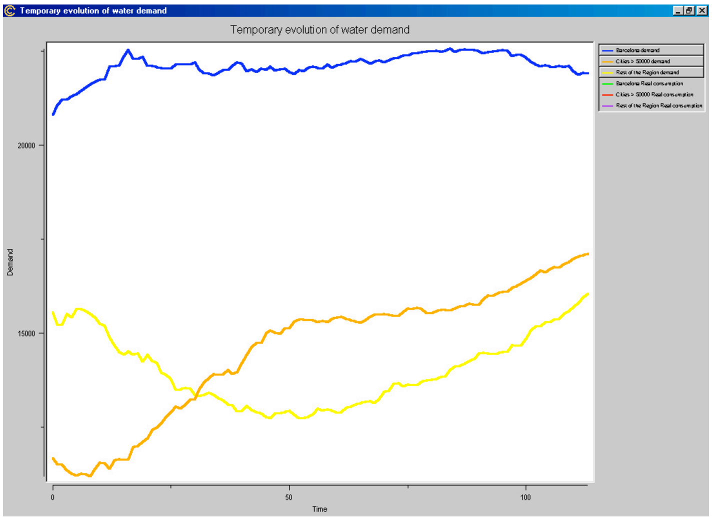


Figure A1.1.3: *Temporary evolution of water demand.*

- Windows to interact with the model. Stakeholders can introduce their preferred strategies to compare the effects on the global system. The simulation can be used to allow to play with different variables, and to test the effect of them under different environmental conditions. The two windows that can be changed during the simulation time are:
  - Policy Price strategy
  - Infrastructure strategy

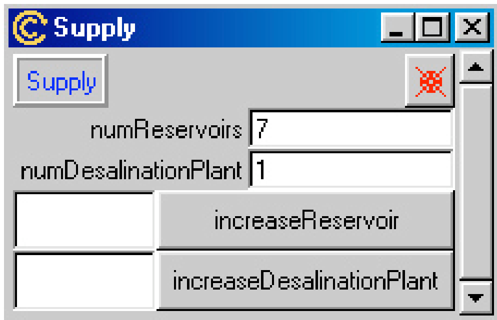


Figure A1.1.4*: Configuration window of Infrastructures*

A1.1.4 Evaluation.

The current interface has not been tested with stakeholders, however, there are plans to introduce the interface to stakeholders in the near future.

A1.1.5 Key findings.

Key findings from the current Java interface are that:

- One of the main reasons to use a Java to complement the SDML programme version is, as well as less computing time, the facilities of Java to build friendly graphic user interfaces to interact with the model and visual outputs. Java is a popular object oriented programming language with the possibility to reuse code of Graphic libraries.
- Probes, used like a GUI object, are one of the most important features of Swarm, the libraries used to create the general Graphic Interface of the Java version. Probes allow the user to dynamically interact with the objects in their simulation. As the simulation progresses, the user can observe and adjust the values of the instance variables. Furthermore, the user can cause objects to execute their methods, taking parameter values or input specified by the user during the simulation generating method calls.

A1.1.6 Technical Appendix

We have used two different libraries to develop the GUI. Swarm libraries and JFreeChart libraries.

The use of the Swarm libraries is based mainly in two reasons:

- The possibility to be used in programs written in Java.
- The powerful of the probes like graphic element and to interact with the model.

In the Java version of the model, the Swarm libraries give support to the grid and the windows to control, to parameter, to interact and some to monitor the simulation.

The use of the JFreeChart libraries is based also in two reasons: they are written in Java and they are publicly available and they provide elements to supply the lack of some useful graphic elements of Swarm, as bars diagrams.

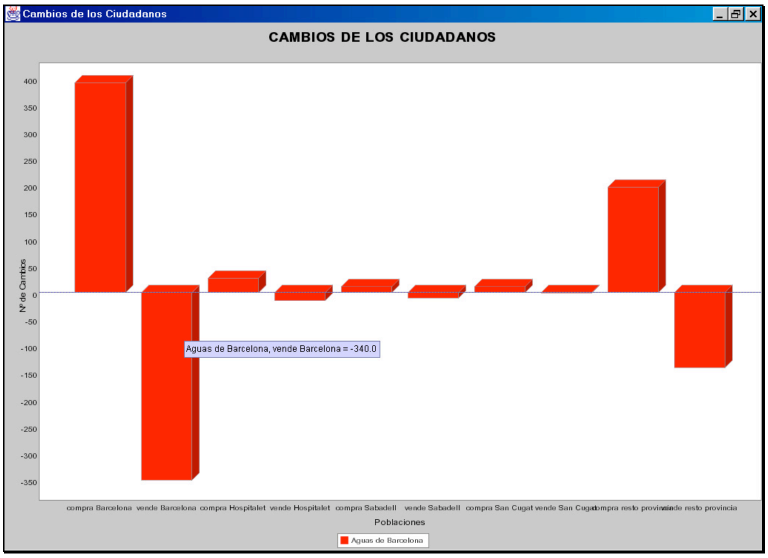


Figure A1.1.5: *JFreeChart example.*

Both are available in Internet. You can find Swarm libraries and how to use them in www.swarm.org . The version that we have implemented in our program is Swarm-2.2. The official home page of the JFreeChart project is http://www.object-refinery.com/jfreechart/ . The version that we have used in this project has been jfreechart-0.9.1.

A1.2 The Maaswerken Negotiation model

A1.2.1 Software Item Identification

The user interface of the Maaswerken Negotiation model is intended for stakeholders who are represented as agents in the combined agent-based and integrated river model. The purpose of this user interface is twofold: firstly, the stakeholder is requested to validate his own representation in the model as well as to validate the relation of his own representation to the environment and other stakeholders. Secondly, stakeholders are confronted with the consequences of their actions/reactions on the environment and are enabled to modify parameters that represent their own goals and beliefs in the agent-based model. Results can be displayed to all participants and can be discussed within a policy maker mediated group session. The interface may be seen as communication and learning tool accompanying a participatory process (see Table 1 in WP3 FIRMA report).

A1.2.2. Intended Users and Functions.

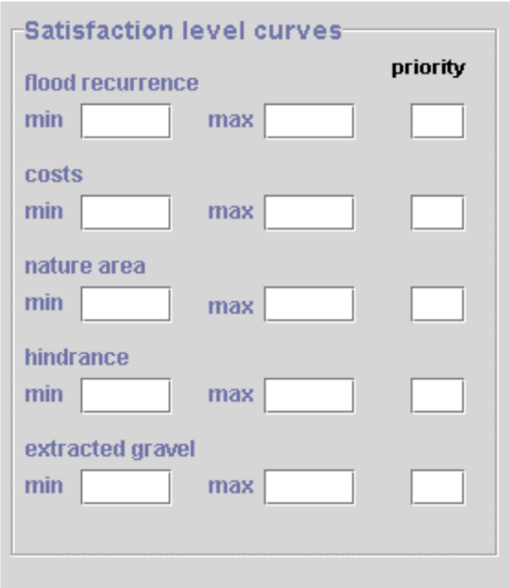
The following users are represented and thus are enabled to use the model/interface:

- Rijkswaterstaat - policy maker who is enabled to propose a strategy that is consists of a set of measures that changes the physical dimensions of the river bed. This stakeholder may also modify his own parameters. The policymaker is simultaneously the mediator of interactive group session.
- Nature organisation - stakeholder who has nature development as central goal, and may react on the proposed strategy of the policy maker.
- Citizen group - stakeholder who has safety as central goal, and may react on the proposed strategy of the policy maker.
- Gravel extractor - executor of a set of measures as part of the entire strategy. The central goal is a profitable coast/benefit ratio of the measures.

In principle there are two types of stakeholders: type (1) – proposing a strategy and type (2) reacting on the proposal. Both types of stakeholders are able to observe the environmental effects. All of them may modify their own parameters as result of a social learning process.

A1.2.3 Design Outline

The interface is designed to use in a sequential way. One of the main design goals is an intuitive use of the GUI, in other words user-friendliness. The user is lead through the interface by tool tips and comments to avoid confusions and wrong or mal-formatted entries. Nevertheless, the user is enabled to modify own parameters, and has, furthermore, the possibility to experiment with the effects of parameter modifications.



FigureA1.2.1: *manipulation of two 'belief' parameters*

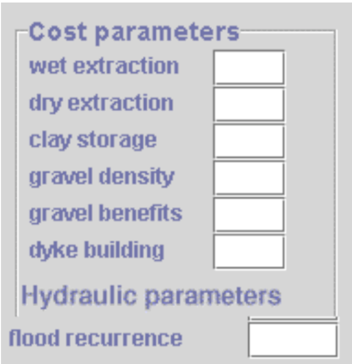


Figure A1.2.2: *Manipulation of goal values*

A1.2.4 Evaluation

The model has not been validated by stakeholders yet. It is still in the laboratory phase and has been tested on a command line version. The sensitivity range of the model is known by the modellers. This knowledge will be implemented (in form of boundary values in the tool tips) for use in the validation phase, and also to communicate realistic ranges of parameter values.

A1.2.5 Key findings

The representation of the environment has to be abstracted for technical reasons. It appears to be problematic to convey this level of abstraction to actual stakeholders and potential users of this model. An introduction for stakeholders is necessary to explain the simplified model relations.

The use of a symbolic representation (goals and beliefs) in the agent model is a promising way to implement real-world observations including stakeholder interests and perspectives in an abstract agent-environment model

A1.2.6 Technical Appendix.

The Java applets have been designed and implemented using Borland's JBuilder 7 with Java version 1.3.1(free download: http://www.borland.com/products/). It is one of the leading development environments. The tool is quite intuitive and easy to use, supporting the design of early prototypes.

A1.2.7 Authorship and Acknowledgements

This work carried out by Krywkow, J. (University of Twente), Pieter Valkering (ICIS) and Elke Mentkes (University of Koblenz)

A1.3 Orb Case Study (SICOPTER Model)

A1.3.1 Software Item Identification

In the Orb case study, the research effort in the design of interfaces for facilitating participatory processes was twofold:

- Develop a generic interface tool facilitating the participatory decisions based on the test of several scenarios. The software aims at being as independent as possible from the model.
- Develop a model of pesticide diffusion in a particular sub basin within a participatory process (Phylou model)

A1.3.2 Software Description

The aim of SICOPTER software is to help the stakeholders to increase and improve their participation in the discussion about envisaged scenarios for water management. We suppose that several possible scenarios of action for the future are identified and the model, which provides the consequences of the envisaged actions, is reasonably accepted and understood by the stakeholders. Our main hypothesis is that two nested dynamics must be considered in a group discussion trying to decide possible future actions (Rousseau 2001):

- The private elaboration of a public position by each participant, which takes into account his own interests, and also the potential reaction of the other participants to his view. We consider that elaboration can be reactivated with the expression of new views by other participants, which may lead to a change in the public opinion.
- The public elaboration of the group position, which is an interpretation of all the public opinions at a given moment. This interpretation may lead to the adoption of the decision, or to acknowledge a conflict situation, or even to agree on the exploration of a new option which appeared in the discussion.

These dynamics are linked by the exchange and the design of concrete representations of the problem called artefacts as described in the distributed cognition field (Grosjean, Fixmer et al. 2000). The whole process can be viewed as a problem formulation which progressively builds the decision problem, both at the collective and individual level (Landry 1995).

Our aim is to propose a software tool which helps the participants in both cycles. In particular, we aim at providing indicators and visual representations of the expressed opinions, which help to identify the areas of conflict or of agreement. These tools could be used by a single participant to help him to elaborate his public opinion, and by the whole group to get a better view of the state of the discussion.

The possibility for distant interactions can modify significantly the process, as well as the role of a moderator / facilitator. So SICOPTER is connected via internet to a database containing results of simulations on different propositions of decision scenarios, used as well to store actor's point of view.

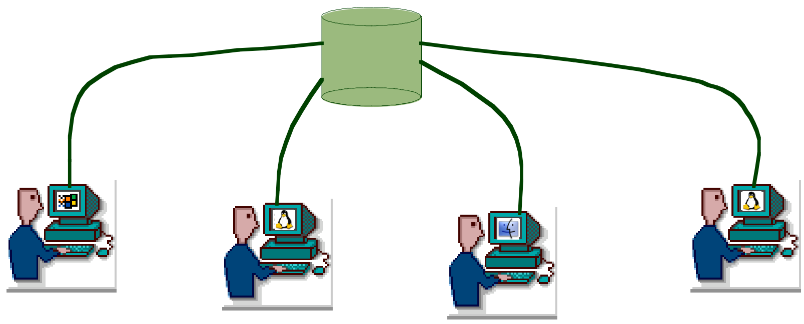


Figure A1.3.1: *the participants are related to a data base of model results, evaluations and comments through internet*

A1.3.3 Intended Users and Functions

This software is to be used by stakeholders, and especially by the animators of the discussion or negotiation process. The users are not supposed to be very familiar with the use of a computer. It should offer them to:

- View model results for different scenarios
- Define thresholds on model results to evaluate the scenarios (i.e. enter their evaluations of the scenarios)
- View other actor's evaluations
- Compare different evaluations
- Comment about evaluations and comparisons

The software is designed to be as adaptable as possible to the results of different models: the database structure has been designed to be as generic as possible. We only suppose that the results of the model fulfils the following constraints:

- The model gives information on a set of objects or locations $O_1, O_2,.., O_p$ of a territory (for instance: a dam, a location on a river or on its bank…), which can be represented on a map,
- A set of attributes $A_1, A_2,.., A_q$ describes each object
- The model provides, for each scenario of action, for each attribute of each object, the corresponding temporal evolution: $S_i O_j A_k(t)$ (for instance: the water level during a particular flood at a given place for a scenario of dike building)

We suppose that the chosen attributes are relevant for the participants and that the values of these attributes over the time are an issue at stake for the discussion. Figure A1.3.2 shows the relational structure of the data into the database.

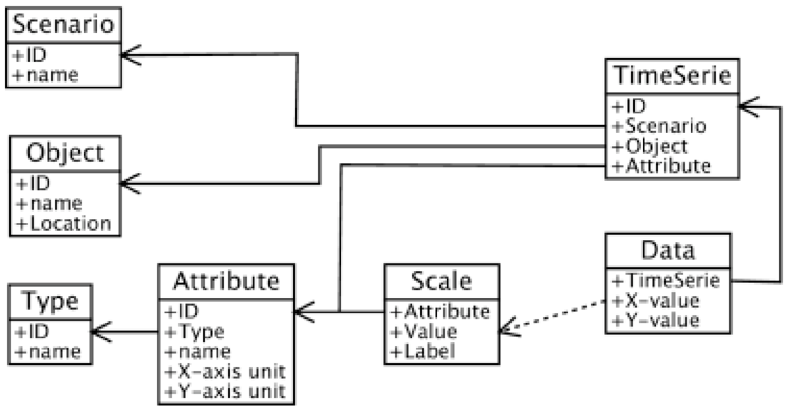


Figure A1.3.2: *Relational model for storing simulation results.*

A1.3.4 Design Outline

A1.3.4.1 Main window

This main window shows the list of evaluations and comparisons made by all actors of the negotiation process. It allows them to create, view or edit evaluations, and create or view a comparison. On the bottom of the window, the user may comment on the selected item (evaluation or comparison). Because it is possible to view or edit many items on the same time, this window is always opened during user's session.

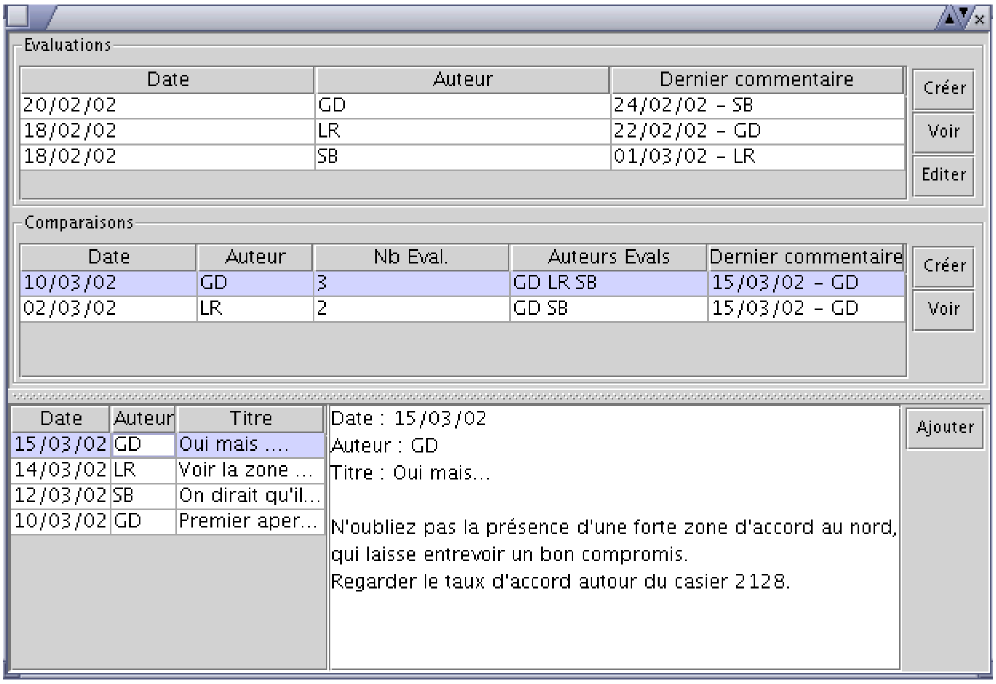


Figure A1.3.3: *Window of discussion archives*

A1.3.4.2 Visualisation window

This window is opened when the user chooses to create, edit or view an item selected into the main window. Some parts of it may be hidden depending on this choice.

It is divided into 3 parts:

- To the left, the actor is able to select scenarios, objects, data type and thresholds he wants to work with.
- On the right top, the data chosen is displayed in an aggregate format for all objects of a same type (it means they have the same attributes), to offer a best view of the interesting objects. It also offers to display statistics on thresholds. The information displayed onto the map may be selected by the use of *"Indicateurs"* menu.
- On the right-bottom part of the window are displayed the whole data (for all time steps) and thresholds for the selected objects. Different statistical representations may be chosen from the *"Indicateurs"* menu.

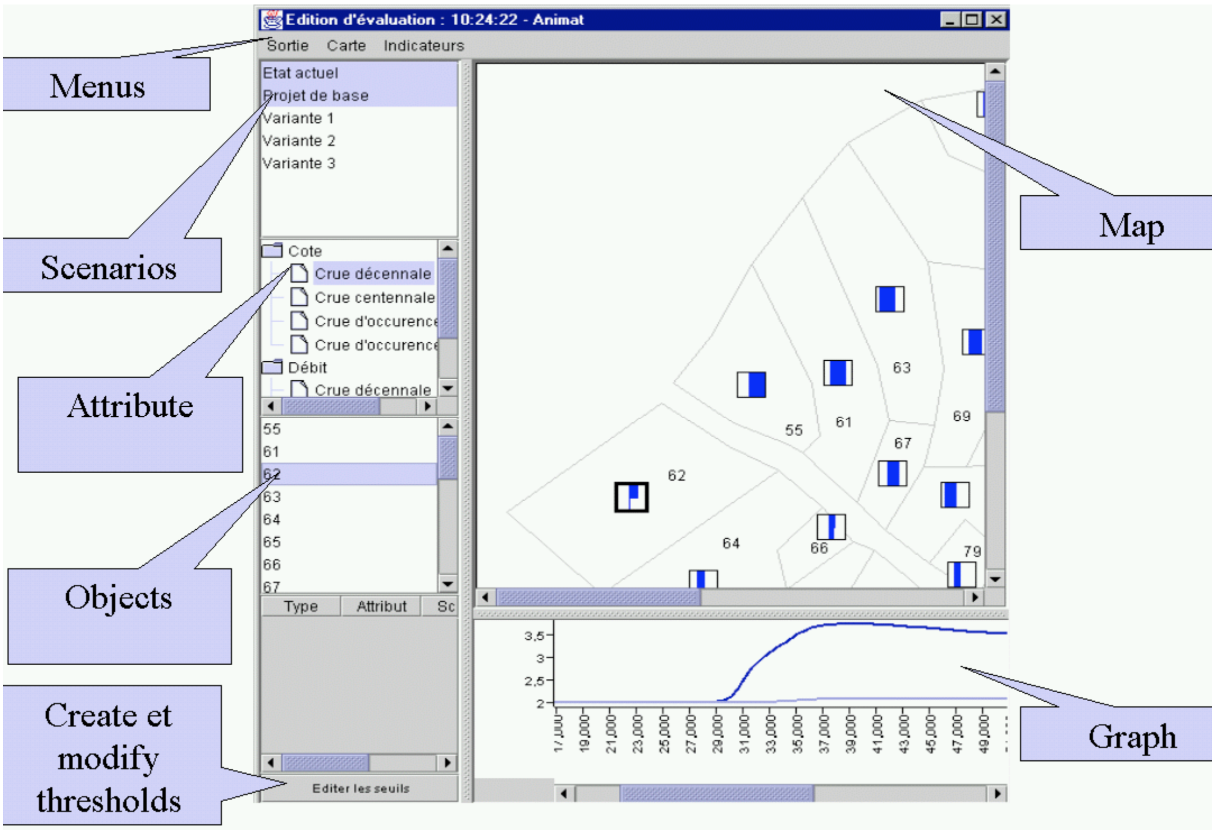


Figure A1.3.4: *evaluation edition window.*

When the actor is creating or editing an evaluation, a button is displayed to open a dialog box to edit, remove or add new thresholds.

The software developed is a light version of a more complete project (see [SIC01]). This first build had the aim of testing basic functionalities for such software designed to be a part of a negotiation process.

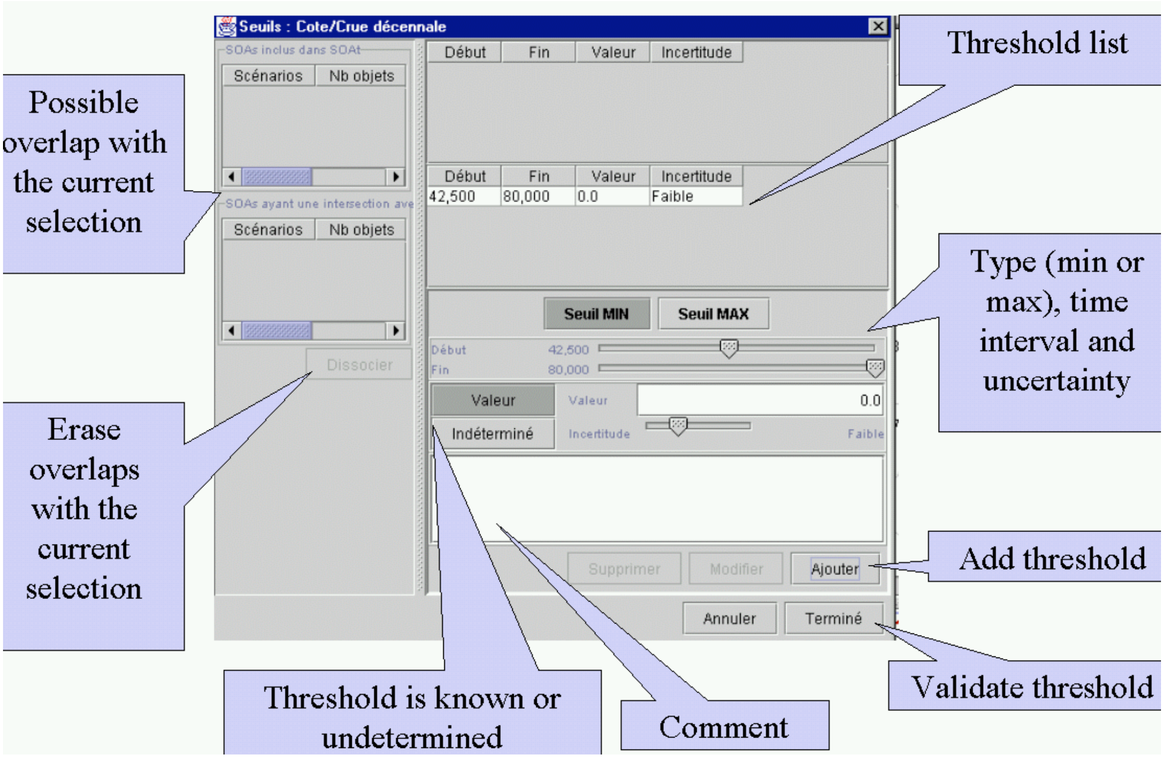


Figure A1.3.5: *Definition or modification of upper or lower levels ofattribute acceptance*

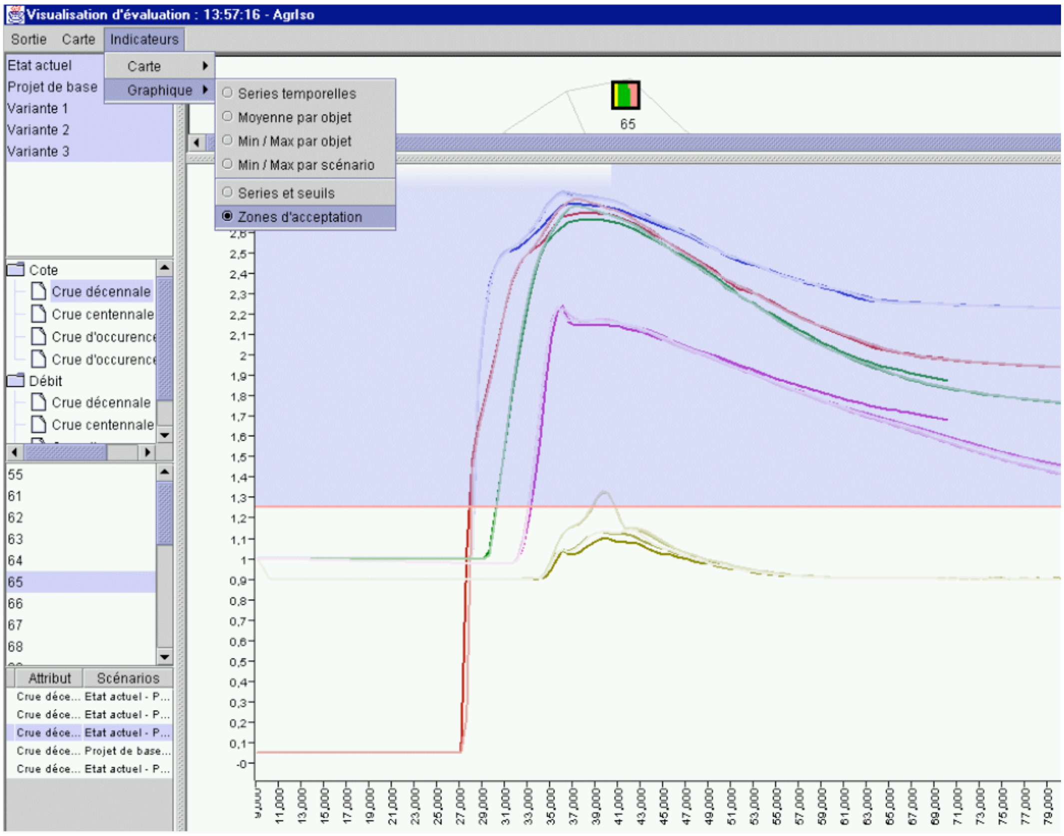


Figure A1.3.6*: acceptance zones for object 65. Corresponding icon appears on map*

A1.3.5 Evaluation

We collaborated with a group of expert technicians from the Orb valley for testing the software, who accepted to play the roles of stakeholders discussing a water management problem. We used a model that was developed by a private company, and is actually used in a current management discussion. The players are experts of this type of discussion. They were not involved in the real discussions but they precisely know the real case. They have immediately done the correspondence between the simulation scenarios and the real case. We already have proceeded to two tests, and we are preparing a third (see scenario report for details about the tests).

A1.3.6 Key findings

The main results of this cycle of tests are that the use of the software requires defining a precise procedure for the discussion. We are currently working with the animator on the definition of such a procedure. In the next test we intend to simulate meetings in which the software is used by the animator for presenting the synthesis of the current state of the discussion. The second test revealed that the position taken in the software is not public in the same sense as an oral position in a meeting. The use of the software must take this into account.

A1.3.7 Technical Appendix

These user interfaces have been deployed using the swing libraries of the Java 2 language. It has been designed with Sun's IDE (forte). It's 100% written in java and has been tested on Windows and Linux platforms. It is connected to an Oracle 8i (8.1.7) back-end database.

A1.3.8 Authorship and Acknowledgements

This work is carried out by L. Rousseau, S. Bernard, G. Deffuant in Cemagref Clermont-Ferrand.

A1.4 Orb Case Study (Phylou Model)

A1.4.1 Software Item Identification

In the Orb case study, the research effort in the design of interfaces for facilitating participatory processes was twofold:

- Develop a generic interface tool facilitating the participatory decisions based on the test of several scenarios. The software aims at being as independent as possible from the model.
- Develop a model of pesticide diffusion in a particular sub basin within a participatory process (Phylou model)

A1.4.2 Software Item Description (Phylou)

Phylou is an agent-based model of pesticide diffusion on a sub basin of the Orb valley. It integrates different hypotheses about the size and distribution of the spots, the border of the spots and the management options of the farmers. The rules of decaying of the different pesticide molecules are included in the model, as well as the flow of water on the soil, ending in the river. The topology of the sub-basin is also taken into account in the model (for more details, see WP3 report).

A1.4.3 Intended Users and Functions.

- Key stakeholders involved in the participatory model design with research team. Purpose is to foster discussion on the representation transcribed in the model itself and mediate the participatory model design process. It is rather a facilitation of communication between a few stakeholders and research team: foster a co-design process and ensuring a common understanding of the model's content.
- Same key stakeholders with initially (and up to now) help from researcher with a larger bench of stakeholders, at least representative institutions, so that they might discuss on the basis of the simulations of the real basin pollutant diffusion issues. Purpose is here to facilitate communication between stakeholders so that they reach a common understanding of the issue at a larger scale than their own farm. Mid-term purpose is that key stakeholders facilitate the discussions using the model as support tool without any help from the research team.

A1.4.4 Design Outline.

Both uses listed above have the same interface features, since the first use is aiming at making key stakeholders more aware of the model potentialities as a discussion support tool.

This interface is featuring static and dynamic representations of space on one hand and time series of pollutant amounts at the outlet.

Figure A1.4.1 is a slot of main dynamic representation of diffusion of pollutants. Brown squares are plots (dark and light brown just intend to make border between two plots appear), while dark green ones are forest and light green are pasture. Blue and red dots are featuring "bullets" of two varieties of pollutants evolving in this virtual basin.

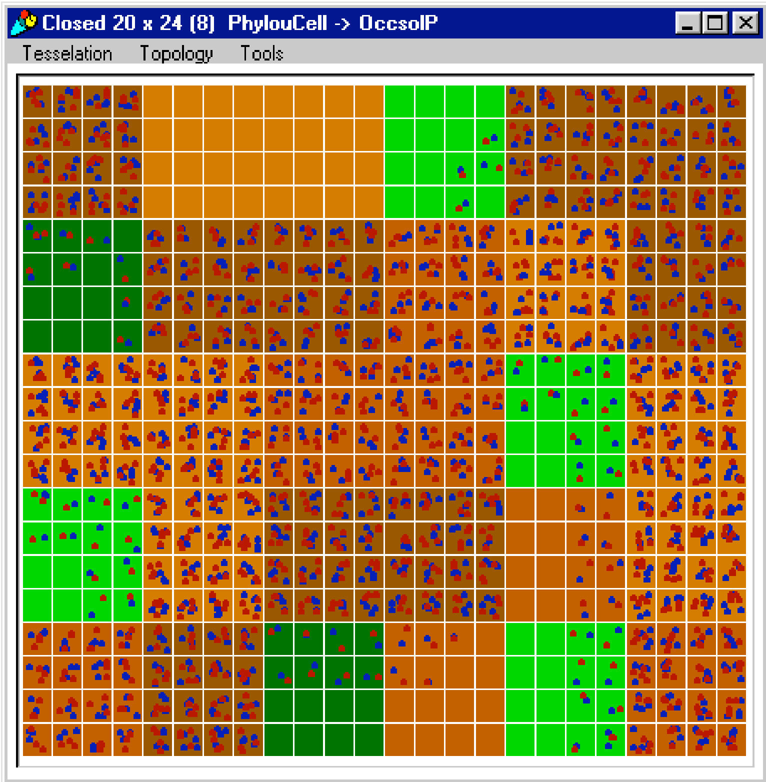


Figure A1.4.1: *presence of pesticides on plots in a depression landscape after 80 days (each red and blue point is featuring a fixed amount of the two molecules simulated)*

Since landscape is a parameter of the model this interface may have various outlook according to the choice of landscape.

Figure A1.4.2 is a static representation of the same landscape featuring the topography of the virtual landscape. It aims at providing users of the model with a few benchmarks so that they may get their bearings.

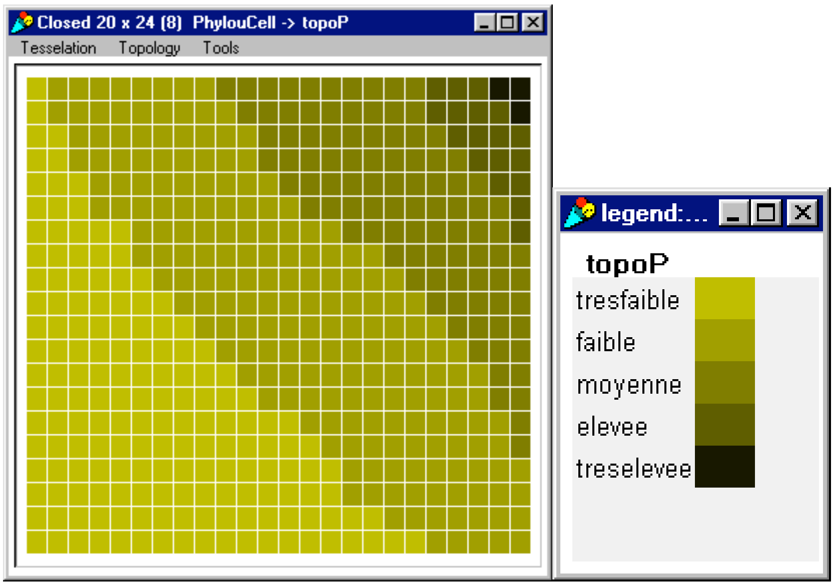
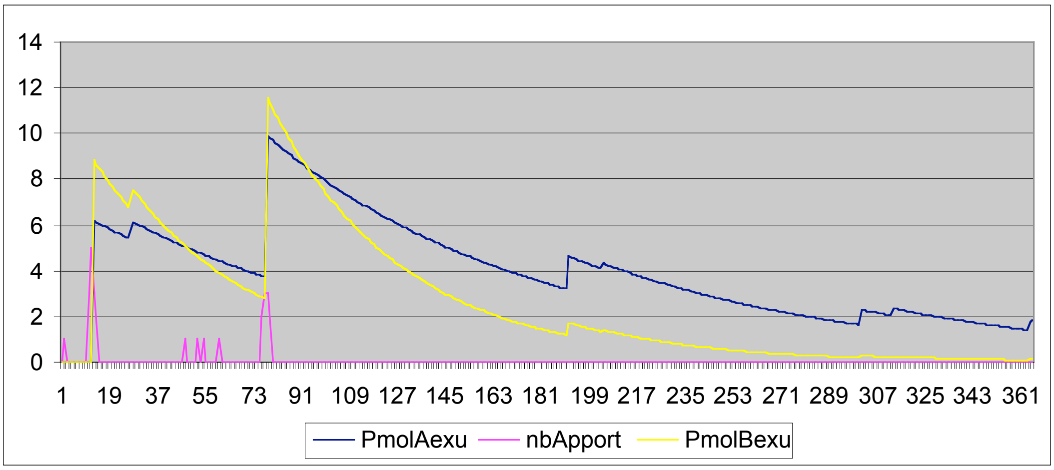


Figure A1.4.2: *lowland landscape topography*

Figure A1.4.3 is a time series of the amount of pollutants at the outlet, according to category.



FigureA1.4.3*: simulations of amount of two kinds of pesticides at the outlet in a depression landscape (in pink are number of farmers supplying pesticides each day)*

A1.4.5 Evaluation

The interface has been tested with key stakeholders that lead to three consecutive interfaces (as well as model versions). We have always used the system ourselves (i.e. one member of the research team at computer's keyboard).

It worked quite well for the first use in the sense that at each time the key stakeholders present were able to get in the model and propose modifications: such as go to the slope scale rather than the whole basin and providing of time series to understand evolution at the outlet of the basin.

Second use is a little less successful since stakeholders wanted to know more on the MAS itself before discussing on the simulations in relation with real system. However it was successful enough so that they were interested to program another meeting focusing on the model.

A1.4.6 Key findings

- Multiplication of viewpoints give stakeholders a better understanding
- Stakeholders may involve in a co-design process of a model through discussion around the interface
- Interface must provide benchmarks to users of the model

A1.4.7 Technical Appendix

We used Cormas platform: http://cormas.cird.fr.

A1.4.8 Authorship and Acknowledgements

This work is carried out by O. Barreteau and F. Cernesson in Cemagref Montpellier.

A1.4.9 References

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Rousseau, L. (2001), “ Computer aided viewpoint comparison as a proposed tool for a constructivist approach of conflict management in group - decision - making.“, IACM’01, Cergy.

Rousseau, L., S. Bernard, G. Deffuant (2002). "Confronting evaluations of scenarios through the Internet" FIRMA report.

A1.5 Thames Case Study

A1.5.1 Software Item Identification

Household Water Demand Model – Thames Case Study

A1.5.2 Intended Users and Functions.

The intended users of the software item are the research team and the research team in conjunction with stakeholders. The purpose is to work together in specifying agents to understand possible consumption patterns under the introduction of new technology and policy exhortations to reduce consumption. The model is intended to give a micro, disaggregated-view of consumption patterns, and their motivations, at a household level. This will generate an aggregate consumption pattern for a community that is based on logical individual behaviour as opposed to a broad following of dominate socio-economic trends.

A1.5.3 Design Outline.

A new version of the model with a new interface is currently being constructed in JAVA. The main reason for the new model platform is to decrease model run time so that it is easier to use interactively with stakeholders. Additionally, the reduced run time will enable batch-mode operation and allow parameter sensitivity testing.

Rewriting the model in JAVA also allows for the development of a new user interface. On the input side, the new interface will present parameters in logical groupings for easier comprehension by stakeholders. Pre-set scenarios will also be available for selection, as opposed to setting each parameter individually. JAVA will also allow the addition of new, dynamic output screens that will enable all users to watch scenario development.

A1.5.4 Evaluation.

The original interface was not tested with stakeholders, inputs and model operation were generally discussed and graphical outputs (assembled from SDML numeric outputs) shown. The interface and model operation were considered too cumbersome to distribute or to run interactively in a workshop forum.

The new interface is currently under development so has not yet been tested with stakeholders. The need for a JAVA model and the input and output design, as discussed in Section 3, is a direct result of working with the SDML model, input interface, operation and output.

A1.5.5 Key findings.

Key findings from the original SDML interface included:

- interface was secondary to the necessity of increased run time
- graphical outputs are easier for stakeholders to understand and useful for researchers in making quick assessments of model outcomes.
- A friendly and intuitive interface is necessary to understand, to interact and to analyse a model for a person who hasn't developed it.

A1.5.6 Technical Appendix.

The University of Chicago's Social Science Research Computing's RePast is a software framework for creating agent based simulations using the Java language . It provides a library of classes for creating, running, displaying and collecting data from an agent based simulation. In addition, RePast can take snapshots of running simulations, and create quicktime movies of simulations.All the libraries can be found in: http://repast.sourceforge.net/

A1.5.7 Authorship and Acknowledgements

This interface report was written by Cindy Warwick and Jose Manuel Galan. The SDML model was written by Scott Moss and Olivier Barthelemy and has been tested and implemented at the Centre for Policy Modelling, MMU and the Environmental Change Institute, University of Oxford. Work on the Java model and interface is being conducted by Jose Manuel Galan at Valliolid.

A1.6 Zurich Case Study

A1.6.1 Software Item Identification

The Zürich Water Game (ZWG*) is a model of the interactions between the public and private sector actors involved in the supply, consumption and purification of drinking water in the city of Zürich. It comes in two versions possessing computer interfaces: a simulation model (ZWG 1) and an internet-meditated business strategy game (ZWG3). Both ZWG1 and ZWG3 are based on an original board game version of a role playing game (ZWG2), already used by the stakeholders during the participatory process.

ZWG1 is a simulation model intended to allow the research team to carry out rapid scenario analysis using Monte Carlo simulation techniques. The results are used to inform discussions about water management within the stakeholder group as well as to calibrate the other versions of the model, ZWG2 and ZWG3. ZWG1 also provides ZWG3 with designs for agent players in the event that individual stakeholders want to play the water game without other human players.

ZWG3 is an internet-mediated business strategy role playing game intended to help stakeholders in Zurich Water Management develop and understand the implications of likely future water scenarios.

A1.6.2 Intended Users and Functions.

For ZWG1 the intended users are members of the research team. For ZWG3 the intended users are the main stakeholders in managing domestic water in Zurich:

- The City Council
- Housing associations
- The Water utility
- The Waste Water utility
- Manufacturers of Water technology
- Professional bodies representing architects, water suppliers and plumbers
- Consumers

For all these users, the software is intended to provide opportunities for individual and collective exploration of alternative scenarios of water resources management in Zurich.

A1.6.3 Design Outline

ZWG 1: The user interface was designed to allow the scientists to easily run Monte Carlo simulations, to view statistical data on the runs and to switch between different agents and parameter settings so as to test them. Hence the main design features involved providing a panel for the observation, and the cut and pasting, of agents in the simulation (Figure A1.6.1, Panel A); the provision of control parameters for running multiple simulations (Figure A1.6.1, Panel B) and the provision of viewers showing graphical information useful for verification purposes (e.g. information about which agents are interacting with each other (Figure A1.6.1, Panel C)). The interface also includes statistical information (see Figure A1.6.2) (e.g. probability distribution functions (PDF) for different output variables), together with point and click methods for saving graphical data directly to excel sheets.

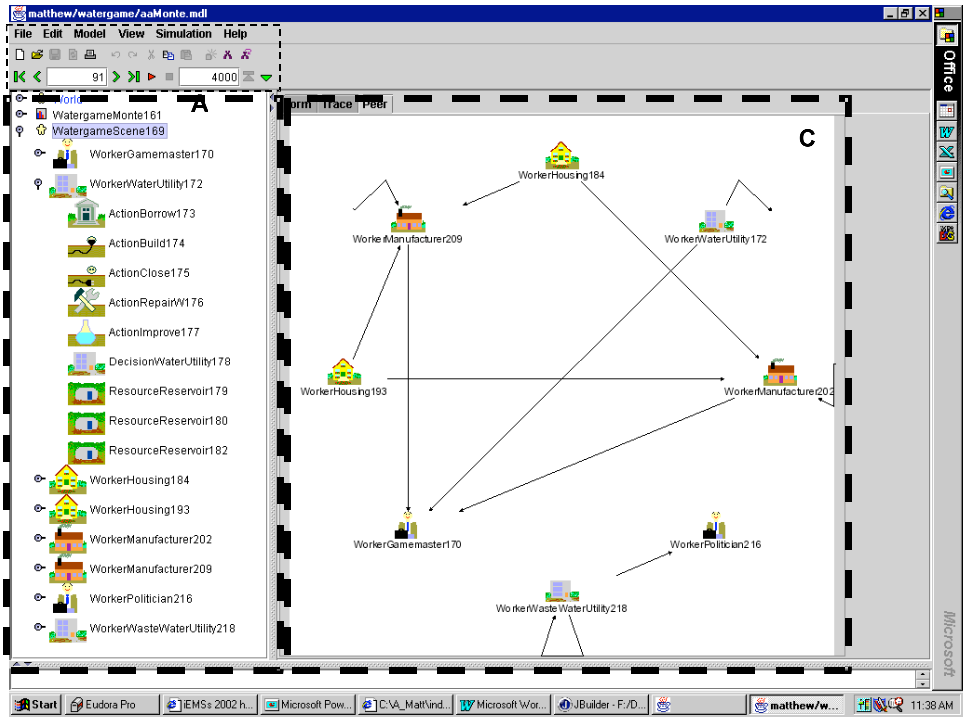

Figure A1.6.1: An interface of ZWG1 illustrating the main simulation control panels

for customising simulations (A & B). Panel C is one of a number of viewing panels that provide real time information about what is happening during the simulation. In this case, it reveals the extent of interactions between the different agents in the simulation.

ZWG 3: The main user interface is a web page, different for each user role, although all conforming to the same basic design. There are also pages of 'instructions' and guidance about the software which are rather more conventional (see Figure A1.6.3) and which the user is required to work through before reaching the main page.

The main page is the page that users interact with throughout most of the game. One design requirement was that it had to offer a great deal of information all of which had to be easily available. Hence a 'tabbed' design was selected (see Figure A1.6.4).

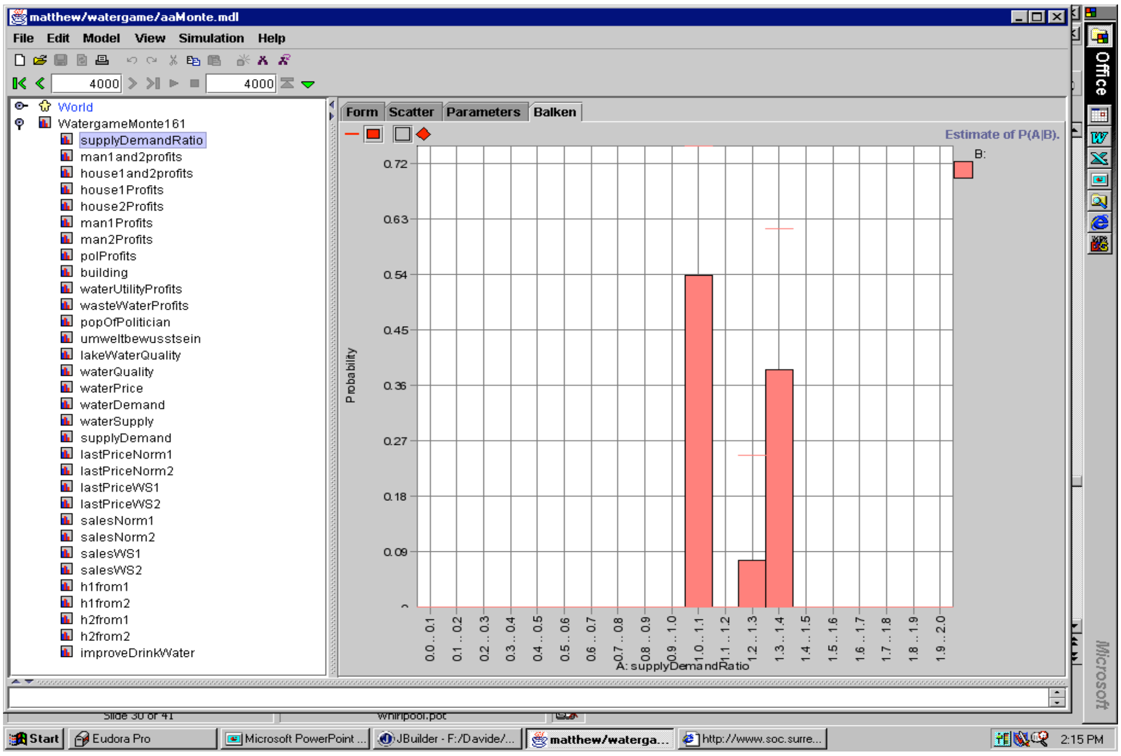

Figure A1.6.2: *An interface of the ZWG1 illustrating the viewers responsible for showing statistical information about the current results of Monte Carlo simulations.*

In this case, the user has selected to view the development of the PDF for the output variable "supply-demand ratio". Users select the PDF to view by pointing and clicking on the appropriate variable name in the left panel. Users change the type of graph viewed by clicking on the tabs at the top of the viewer panel.

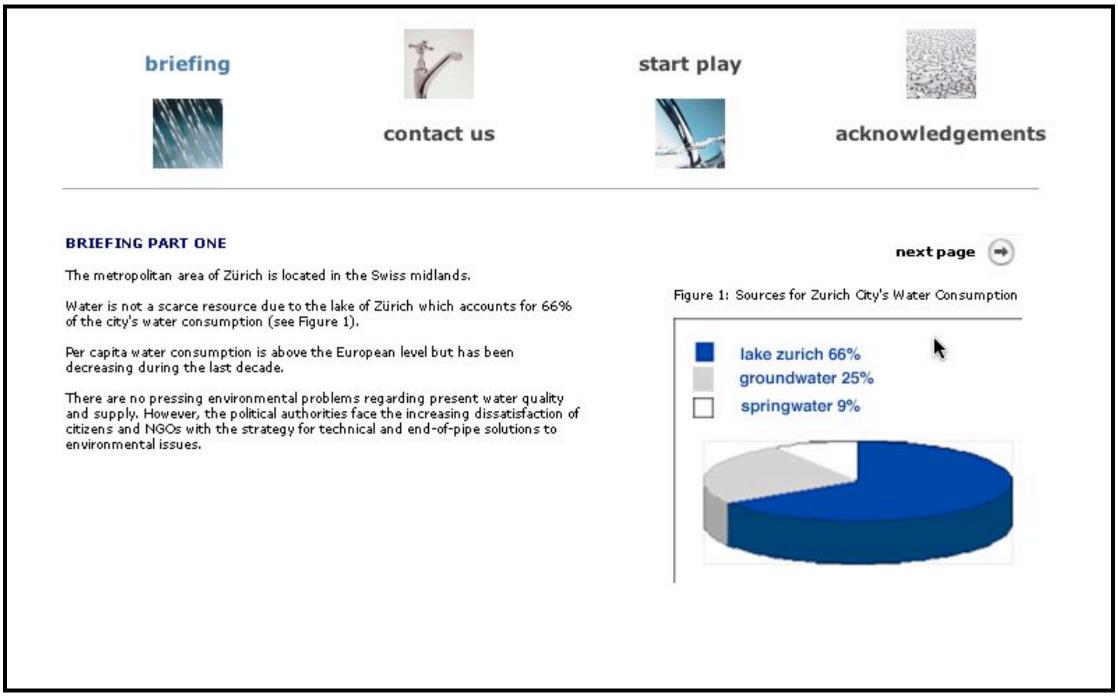

Figure A1.6.3: *Sample 'briefing' page.*
When the user has read the text, he/she clicks on the arrow to move to the next page.

On the left hand side, the user can choose one from a small number of possible 'actions' and must also enter a brief textual justification for their choice. At the top of the left side, there are icons (in the case illustrated, Houses) that indicate the status of the resources that this user is managing. Most of the right side of the screen is used for a set of tabs and associated panels. Clicking on one of the tabs ('diary of events', 'public negotiations', 'private negotiations', 'other players' or 'help') replaces the panel with another (see for example, Figure A1.6.5, which illustrates the effect of having clicked on the tab labelled 'Other players'.

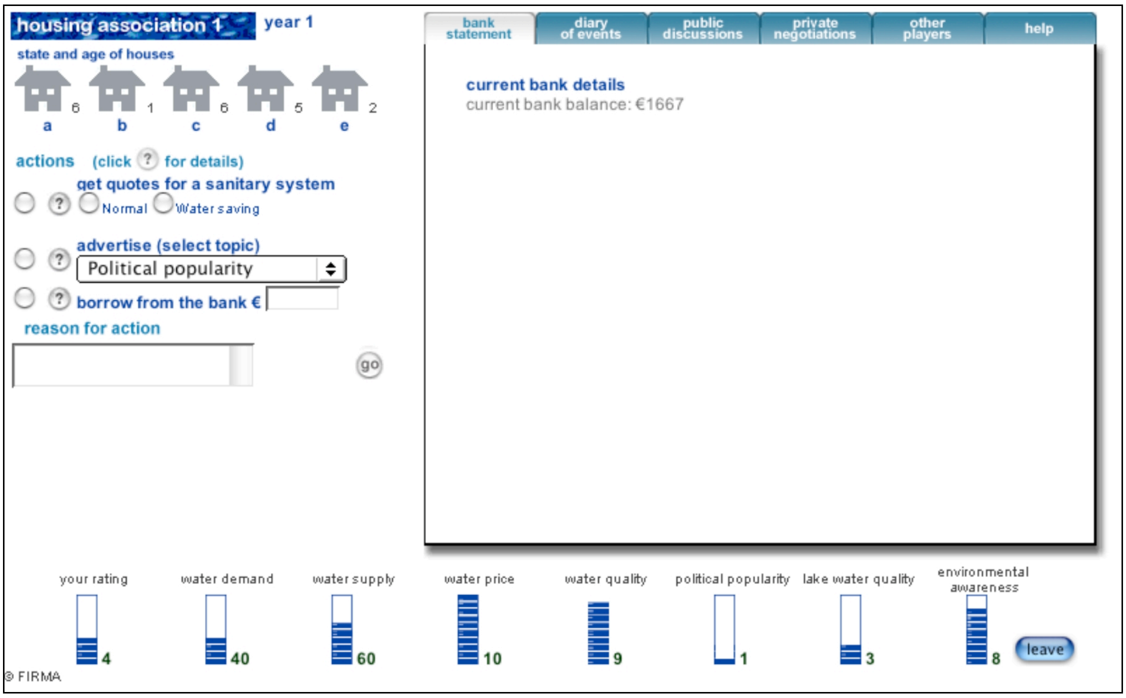

Figure A1.6.4: *The main page as seen by the Housing Association user*

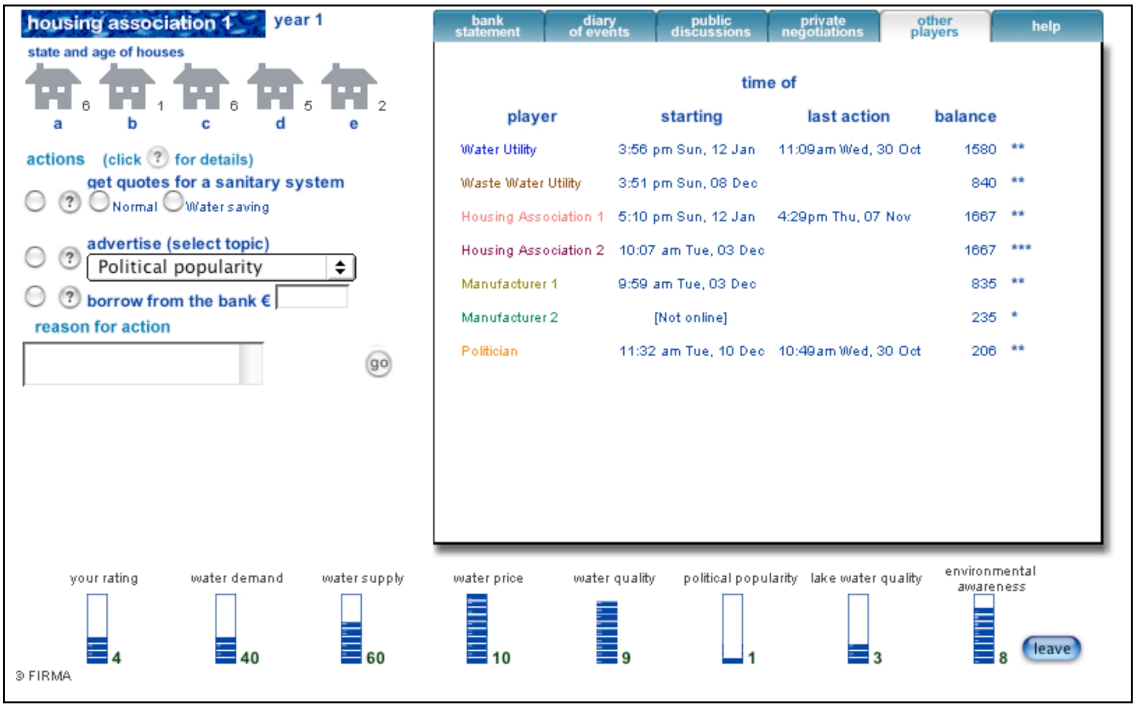

Figure A1.6.5: *The same page, after having clicked on the 'Other players' tab*

Below the panel, across the bottom of the page, is a row of gauges. These indicate the overall status of the game (e.g. the level of water demand). Moving the mouse cursor over these, or over one of the '?' icons next to the action buttons, temporarily replaces the contents of the tabbed panel with a help text (Figure A1.6.6).

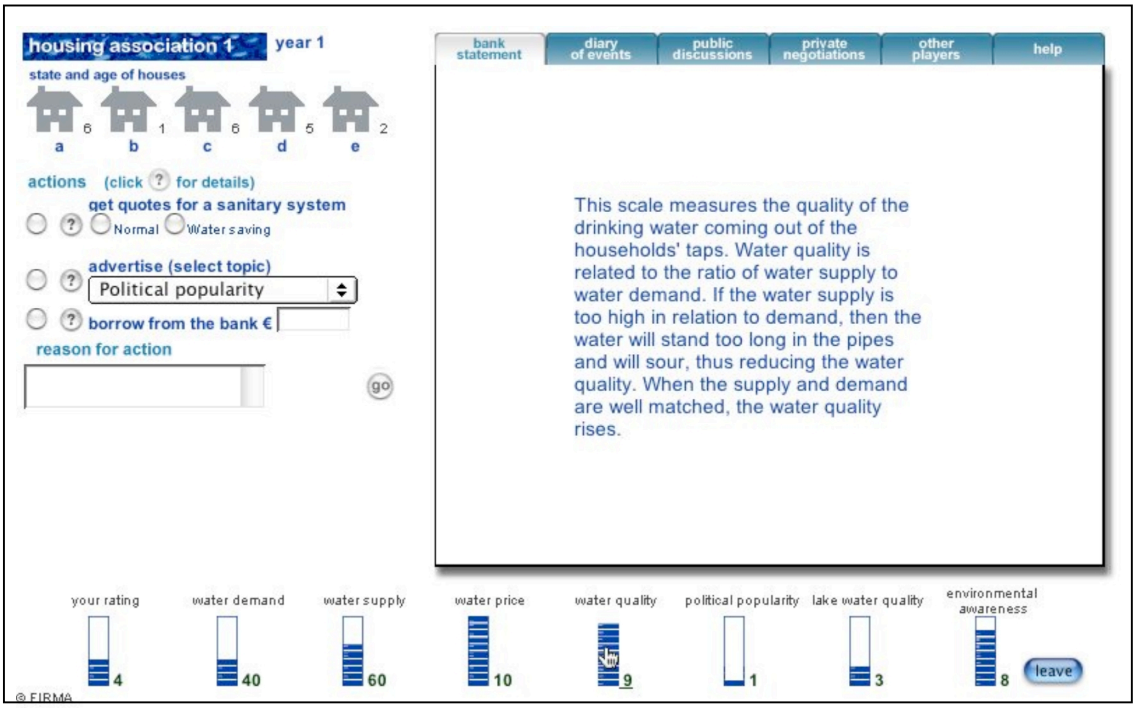

Figure A1.6.6: *Moving the cursor over the Water Quality gauge displays information about it*

A1.6.4 Evaluation

ZWG 1: This was tested by the research team. The main areas that needed changing included allowing the user to move stepwise through a simulation at different rates, as well as to be able to go backwards through a simulation without having to repeat the whole run from time zero. Also it required a real time viewing interface for viewing simulations as they ran as well as a batch version.

ZWG 3: The user interface was extensively tested during development by members of the project team, playing the roles of the intended users. This testing revealed a number of difficulties, mainly due to programming errors or lack of support for the whole range of Dynamic HTML and CSS by the most common web browsers. Most of these were overcome.

The user interface was then translated into German and will be evaluated by the users themselves.

The most serious difficulty encountered was that in order to support all the functionality described above, the capabilities of web browsers were pushed to the limit. Intermittent problems of graphics (e.g. the tabs) not being displayed are still being encountered. Even the most recent versions of the Netscape/Mozilla browsers do not correctly support scrolling within elements, although this has been a feature of the CSS standard for some years. This has meant that only Internet Explorer is at present able to be used as the web browser for accessing ZWG3.

The tabbed panel design was effective in presenting a great deal of information to the user such that it was all available just a click away. However, users did sometimes find it confusing to have to keep changing panels using the tabs, especially when information on a hidden panel changed while they were not looking at it. There were therefore some problems with maintaining players' awareness of their own and others' activities during a dynamically changing game.

A1.1.5 Key Findings

- Different interfaces are needed for different purposes and different stakeholders. The interface for ZWG1 used by the research team, for example, is naturally less user-friendly but allows more sophisticated and open-ended, flexible interaction than ZWG3 interface. The latter, used by stakeholders, however, provides superior help advice and pays more attention to HCI issues regarding usability.
- Careful thought has to go into methods of making a great deal of information easily and quickly available to users of this type of game.
- Current web browsers are not able to support completely and accurately the rather sophisticated use of Dynamic HTML and CSS that the current design involved.
- The early involvement of a graphic designer or someone with a good sense of graphic design is crucial in making an effective user interface.
- Usability testing of the interface is essential. Work schedules should allow for many iterations of such testing before interface and programming 'bugs' are all found and removed.

- The provision of meaningful Help information is of vital importance for aiding players in a non face-to-face playing environment such as the internet version of the Zürich water game (ZWG3).
- Moving from a board game version of a role playing game played between players who are face to face (ZWG2) to an internet version (ZWG3), in which players are no longer in the same room, is not easy.

A1.6.6 Technical Appendix

ZWG1: The interface software was built using Java Swing (http://java.sun.com/docs/books/tutorial/uiswing/) and a set of libraries for creating agent-based simulations designed by Jan Burse called Quicksilver (http://www.internal.eawag.ch/~mmoptmod/core/intro/welcome/index.html).

ZWG3: The software was built using the Apache (www.apache.org) web server, with the PHP web scripting language (www.php.net). Web pages were coded in HTML (including dynamic HTML extensions) (http://www.w3.org/MarkUp/), CSS1 (http://www.w3.org/Style/CSS/) and Javascript (the standard version of which is now called ECMAscript, http://www.ecma.ch/ecma1/stand/ecma%2D262.htm). The software also used a relational database, PostgreSQL (www.postgresql.org).

A1.1.7 Authorship and Acknowledgements

The series of water games (ZWG1, 3) are based on an original role playing game the Zürich Water Game (ZWG2), designed by a team consisting of: Matt Hare, Felix Huber, Johannes Heeb, Claudia Pahl-Wostl. Tested with the help of the Zürich case study stakeholders and Nigel Gilbert and Tasia Asakawa.

ZWG1 was designed, built and tested by a team consisting of: Matt Hare, Davide Medugno, Claudia Pahl-Wostl, Jan Burse (user interface design).

ZWG3 was designed, built and tested by a team consisting of: Tasia Asakawa (testing), Nigel Gilbert (coding), Matt Hare (specification), Sarah Maltby (user interface design). And other members of the FIRMA project

APPENDIX 2. CASE STUDY REPORTS ON SCENARIO GENERATION AND USE

A2.1 Scenario Development For The Barcelona Case Study

Mercè Capellades, Mònica Rivera & David Sauri

The elaboration of scenarios of domestic water demand for the Metropolitan Region of Barcelona (MRB) counting with the active participation of our stakeholders platform has been one of the fundamental objectives of our case study. The MRB has suffered in the past a number of episodes of water stress. Conventional approaches to water planning and management have emphasized the need of solving water stress through the increase in water supply, most notably by building a large inter-basin transfer. However, some demand management actions are also being applied in many municipalities of the region. Particularly important are the change form bulk to metered water and the adoption of prices and taxes based on tariff blocks. Scenario building aims at simulating the evolution of domestic water demand according to different hypotheses but no attempt is made to quantify the likelihood of these foreseable futures. Instead, the selection of one scenario for the application of our agent-based model derives from stakeholders assessments of the hypotheses presented to them.

The construction of scenarios has involved a process consisting of four parts:

1. Development of hypotheses or statements regarding possible trajectories of different components of the water cycle in the MRB. These statements were prepared by the Barcelona team after a general model provided by the Oxford team, and were elaborated taking into account recent trends in Climate, current resources, supply alternatives, and demand alternatives.

2. Individual interviews with an average duration of one hour and a half for each of the stakeholders of our platform. In these interviews and by means of a questionnaire stakeholders were asked to express their opinion or qualitative assessment on each of the propositions presented according to three general categories: "Highly Plausible". "Plausible", and "Little Plausible" (see our poster presented in the Clermont Ferrand meeting for results on this categorization).

3. Elaboration of three scenarios on domestic water demand and on the feasibility of options to correct water stress. Scenarios were built by grouping answers to the questionnaire according to the degree of consensus obtained . Scenarios were defined respectively as “High Water Demand”; “Medium Water Demand”, and “Low Water Demand”. Each scenario contained four main themes: Climate; Water Demand, Influencing Factors, and Resources. The starting point for each scenario was a situatio of imbalance between water supply and water demand. The “High Demand” scenario considers 1) an increase in demand due to the continued expansion of the low density urban pattern; 2) little development of demand management alternatives, and 3) an increase of water supply through the construction of inter-basin transfers, and desalinisation plants. The “Medium Demand” scenario maintains the hypothesis of low density urban growth but gives more emphasis to water demand management alternatives (wastewater and rainwater use; recovery of now degraded local groundwater resources; more presence of efficient domestic water technology; higher prices in municipalities where water is relatively unexpensive now; creation of water markets, and decrease in distribution losses). The application of these measures would then make unnecessary the enhancement of conventional supply sources. Finally, the “Low Demand” scenario would imply the decrease in importance of the low density urban model; the aplication of water demand alternatives and the non consideration of new, conventional water supply sources.

4. Discussion of scenarios with the stakeholder platform and elaboration of a simulation model. The three scenarios were presented to our staholder platform in two meetings. The first was attended by representatives of ACA and AGBAR while the second was attended by representatives of CONFAVC, ROCA, OCUC, and ATLL. The remaining stakeholders (AV and APCE) could not attend any of the two meetings. The conclusion reached from the discussions was that the “Medium Scenario” appeared as the one more plausible. The “High Scenario” was seen as “unsustainable” and therefore highly unlikely in the current context, while the “Low Scenario” was seen as “unrealistic”. The adoption of the “Medium Scenario”, however, was

somewhat qualified by some of the stakeholders. Thus, ACA and ATLL agreed on the need of impulsing water demand alternatives but together with and not instead of the development of conventional water supply alternatives (the rationale being that the management of water demand alone could not provide for the increase in demand derived from the low density urban model). Other stakeholders (CONFAVC, AV and OCUC) insisted in reinforcing actions addressed to correct urban sprawl. The remainder stakeholders (AGBAR, APCE and ROCA) did not introduce any qualifications to the "Medium" scenario.

The agent-based simulation model built according to the specifications of the "Medium" scenario represents the final step of the process. This model will be presented in the final meeting to be held with stakeholders late January 2003.

A2.2 Scenarios In The Maaswerken Case Study

Maaswerken Team

A2.2.1 Introduction

The objective of our case study is to define quantitative integrated scenarios for river management with the ultimate aim to identify robust strategies for river management. The time horizon is the year 2020; the year when the Maaswerken project is expected to be finished.

The scenarios are derived from the Maaswerken Negotiation model (the combined Agent Based – Integrated River Model described in the report on WP 3). This model is used to calculate a number of impacts of river engineering measures and the associated satisfaction levels of stakeholders. The river engineering impacts include the long term decision-making criteria flood risk, nature area, and an ecosystem distribution index (EOW index), and implementation costs: monetary net costs and hindrance levels.

The perspectives of the stakeholders of the Maaswerken are explicitly incorporated in the model calculations. Two aspects of stakeholder perspectives can be distinguished: their perspectives on uncertainty and their perspectives on evaluation. The perspectives on uncertainty are used to arrive at different projections for the impacts of a given river management strategy. To this end, the uncertainties in the Integrated River Model are made explicit in the form of uncertain model parameters that are filled in according to stakeholder beliefs. Stakeholder perspectives on valuation determine which river management strategy is chosen. Therefore, we calculate the satisfaction of stakeholders for given values of the decision-making criteria, leading to an acceptance or decline of a proposed river management strategy.

The approach is similar to the concept of model routes of (Rotmans, van Asselt et al. 1997). The main difference is that we use stakeholder beliefs to classify uncertainties instead of the cultural stereotypes of (Thompson 1997) adopted in (Rotmans, van Asselt et al. 1997)

A2.2.2 Uncertainties

In the following we describe four salient uncertainties that are explicitly included in the Integrated River Model.

A2.2.2.1 Climate change and river discharge

Climate change may drastically change the discharge pattern of the Meuse, both in terms of average seasonal discharges and peak flow probability. We adopted three discharge scenarios for the Meuse at Borgharen from the study 'Waterbeheer 21ste eeuw' (Commisie Waterbeheer 21ste eeuw 2000). They developed three scenarios on the basis of global temperature increases of 1^{o}C (low scenario), 2^{o}C (central scenario), and 4^{o}C (high scenario) by 2100. The results for the year 2020 (based upon linear interpolation for the period 2000 – 2100) are displayed in Table A2.2.1:

	Current	**Low**	**Central**	**High**
Summer discharge (May – Okt)	142 (m^3/s)	+ 0.3%	+ 0.5%	+ 2%
Winter discharge (Nov-Apr)	344 (m^3/s)	+ 3%	+ 6%	+ 11%

Table A2.2.1: *Discharge scenarios at Borgharen for year 2020.*

Stakeholders may also choose to neglect climate change for the year 2020 and adopt the current discharge characteristics.

A2.2.2.2 Hydraulic roughness

Hydraulic roughness is a crucial parameter for calculating the river water level as a function of discharge. Its value depends strongly on the fraction of high vegetation (shrubs and forest) in the vegetation that will arise alongside the river after execution of river engineering measures. We adopted three possible assumptions for this fraction:

- **Low**: 0% shrubs/forest
- **Central**: 20 % shrubs/forest
- **High**: 50 % shrubs/forest

A2.2.2.3 Morphological dynamics

We adopt three legitimate estimates for the amount and type of erosion in the river channel. More specifically, we adopt three possible assumptions for elevation change of the broadened summer bed after execution of measures:

- **Sand dunes and gravel banks**: elevation of the broadened summer bed equals water level at yearly average discharge (see (Bureau Stroming 1991))
- **Low erosion**: 0.5 meter lowering of the broadened main river channel
- **High erosion**: 1.0 meter lowering of the broadened main river channel

The latter two values are based on expert judgment of the engineers of the Maaswerken planning organization.

A2.2.2.4 Calculating costs and benefits

The calculation of costs and benefits of river engineering measures depends critically on the values of the cost parameters shown in Table A2.2.2. We include two consistent sets of assumptions for the values of these parameters: a positive set, leading to the lowest net costs, and a negative set, leading to the highest net costs, see Table A2.2.2. The cost parameter values and uncertainty bands are based on expert judgment of the engineers of the Maaswerken planning organization.

Uncertain cost parameters	Positive	Negative
Excavation costs (EURO/m^3)	3	3.5
Soil processing costs (EURO/m3).	4	5
Soil density (ton / m^3)	1.9	1.8
Soil fraction gravel : sand	75:25	70:30
Benefits of gravel (EURO/ton)	7	6.5
Benefits of sand (EURO/ton)	4	3.5

Table A2.2.2: *Two possible sets of cost parameter estimates: a positive and a negative estimation.*

A2.2.3 Perspectives on uncertainty

We have grouped the choices for uncertain parameters in a consistent way according to stakeholder perspectives. This was done on the basis of information available to us from interviews and a number of reports on stakeholder participation in the

Maaswerken. More detailed knowledge elicitation is still to be performed by means of stakeholder workshops. The results displayed in Table A2.2.3 are thus preliminary.

Uncertainty **Stakeholder**	**Climate change**	**Hydraulic roughness**	**Morphological dynamics**	**Costs and benefits**
Policymaker	Current	Central	Low erosion	Positive
Nature organization	High	High	Sand dunes and gravel banks	Positive
Gravel extractor				Negative

Table A2.2.3: *Preliminary results for stakeholder perspectives on model uncertainties.*

A2.2.4 Perspectives on valuation

The satisfaction levels of stakeholders for given values of the decision-making criteria are calculated by means of so called satisfaction level curves. A typical satisfaction level curve is depicted in Figure A2.2.1. The curve describes the satisfaction of the stakeholder 'nature organization' for the decision-making criterion 'nature area'. The satisfaction level curve shows a unacceptable range (value is below the minimal requirement), a acceptable range (value is above desired value) and a negotiable range (value may be accepted during negotiation).

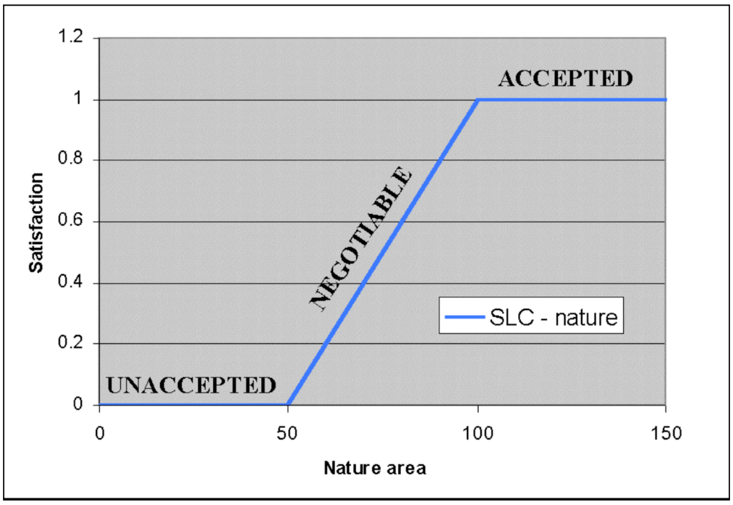

Figure A2.2.1: *A typical satisfaction level curve describing the satisfaction of stakeholder 'nature organization' for the decision-making criterion 'nature area'.*

A2.2.5 Integrated scenarios for river management: preliminary results.

A2.2.5.1 Quantitative scenarios

We have assessed two possible river management strategies with the Maaswerken Negotiation model: the so-called Preferred alternative (Maaswerken 1998) and Green for Gravel alternative (Bureau Stroming 1991). This resulted in three scenarios for each strategy, as displayed in Table A2.2.4. The table includes decision-making criteria (printed in **bold**) and a number of illustrative state variables (printed in *italic*). The boxes of decision-making variables are shaded indicating the satisfaction range of the stakeholder to this parameter value: white = accepted, light grey = negotiable range, dark gray = unacceptable.

	Preferred alternative			Green for Gravel		
Stakeholder	**pm:**	**no:**	**ge:**	**pm:**	**no:**	**ge:**
Future state:						
Flood recurrence (years)	**823**	**174**	**1012**	**953**	**206**	**1345**
Water level decrease (meters)	*0.37*	*0.24*	*0.42*	*0.4*	*0.28*	*0.46*
Critical discharge (m3/s)	*3694*	*3471*	*3779*	*0.4*	*0.28*	*0.46*
Nature area (ha)	**75**	**75**	**75**	**100**	**100**	**100**
EOW index	**86**	**67**	**86**	**56**	**50**	**56**
Implementation costs and benefits:						
Extracted gravel (mln tons)	**6.6**	**6.6**	**6.2**	**7.9**	**7.9**	**7.5**
Costs (mln EURO)	*44*	*44*	*51*	*56*	*56*	*64*
Benefits (mln EURO)	*55*	*55*	*48*	*67*	*67*	*58*
Net Costs (mln EURO)	**-10**	**-10**	**3**	**-11**	**-11**	**6**
Hindrance (1000 person*days)	**31**	**31**	**31**	**40**	**40**	**40**

Table A2.2.4: *Quantitave scenarios for 2020 as produced with the Integrated River Model Shaded boxes refer to the satisfaction level of the stakeholder to the value of the decision-making criterion.*

A2.2.5.2 Interpretation of the results

Both strategies seem to provide the village of Borgharen with the generally accepted safety norm of 1:250 years. Only from the nature organization perspective the safety level is slightly below this norm as this stakeholder assumes a high level of climate change. The main difference between the two strategies is the scale of measures. The Green for Gravel strategy foresees more river bed widening, more gravel extraction and higher hindrance levels for inhabitants. It may be both the more profitable strategy (according to the policymaker) as well as the most expensive one (according to the gravel extractor). In the Green for gravel strategy a larger area is reserved for nature. However, the distribution of ecosystems is better balanced for the 'Preferred alternative'. The values of the EOW index do not vary strongly between stakeholder perspectives.

This model exercise shows that the Preferred alternative is closer to a consensus strategy then the Green for gravel alternative. The main bottle necks for the Green for Gravel strategy are a high unacceptability for the gravel extractors and hindrance levels in the negotiable range for the policy-maker. In the Preferred alternative both the safety level and hindrance levels are accepted for all stakeholders. Nature area may be initially only within the negotiable range for nature organization, but they are likely to accept during negotiation. The gravel extractors, however, can still not accept the strategy. Execution of river engineering measures can only take place when they are additionally funded or are granted concession for additional gravel extraction.

A2.2.6 Conclusion

The method outlined above is promising for developing integrated scenarios for river management. The method shows clearly the bands of uncertainty in estimating impacts of river engineering measures. Furthermore, it gives insight in the underlying motivations for choosing a river management strategy. However, the Maaswerken Negotiation Model should be further developed in participation with stakeholders to gain a better understanding of actual stakeholder perspectives on uncertainty and valuation.

A2.2.7 References

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A2.3 Scenarios in the Orb Case Study

Orb Team

A2.3.1 Introduction

In the Orb case study, the research effort took 3 complementary directions :

1. Compare models coupling hydrological and social models of water consumption at different scales, in order to identify the potential of individual based approaches.
2. Develop a model of pesticide diffusion in a particular sub basin within a participatory process (Phylou model)
3. Develop a software tool facilitating the participatory decisions based on the test of several scenarios.

In each of these research directions we used some kinds of "scenarios". However, this word covers a large variety of nuances, which are explained below.

A2.3.2 Scenarios as Experiment Designs for Comparing Models Water Consumption at Different Scales[2]

A2.3.2.1 Comparing models at different scales

Here we recall the main features of our model following the description which was made in the Work Package 3.

This model deals with water quantity in the Orb River Basin. Water withdrawals depend on the one hand on agricultural practices linked to irrigation, on the other hand on domestic use, which vary in time and over the year. Link is performed over aggregate withdrawals, on the one hand and feed-back of the state of the resource on the other hand. Water consumptions evolve depending on the social context and on the state of environment, and impact on the water resource.

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[2] This work is carried out by M. Edwards in collaboration with S. Huet and F. Goreaud in Cemagref Clermon-Ferrand

This model takes sense in a series of models. The purpose is not to be predictive, but to compare population and water models linked around the question of quantitative evolution of the resource, at different scales, and more specifically, the possible advantages in this context, of individual over aggregate description for the population sub-model. If the aggregate model approximates the individual-based one (more costly in time and memory) it can probably favourably replace it.

A2.3.2.2 Purpose of the scenarios

The scenarios aim to explore and validate the behaviour of the models, and allow fruitful comparisons between them. We seek to understand the impact of various parameters on the behaviour of the models and on their eventual difference. We expect that the linked model with the deterministic aggregate social sub-model approximates the mean results from the one with the stochastic individual-based one. We try to understand how the parameters influence the variability of the results of the latter, and when this variability can lead to invalidate the approximation of the deterministic model.
Therefore, without seeking to explore all possibilities, the scenarios are nevertheless often lead outside the ordinary bounds of realism.

A2.3.2.3 Scenarios

We suppose the water regime varies monthly but is annually stable (the rains are the same from one simulation year to the other). In this way we can isolate the influence of water consumption practices on the water resources. (Besides, at the horizon we consider (less than ten years) this hypothesis seems justified.)

We tackle more specifically various possible sources of difference between the models : the role of stochasticity versus determinism (and the sources of variability in the individual-based model), the number of individuals, the mean number of relationships and their configuration, the frequency of re-evaluation of the behaviours…

The scenarios aim at isolating a specific source of possible difference.

We define a state of reference which corresponds to intermediate values of parameters. We then test the influence of each parameter on the results of the comparison by letting this parameter vary around its reference value and by then comparing the results of the models for these different values of parameters. The values for which the difference is the least minimise the impact of the factor on the difference ; they may allow us to isolate as much as possible the impact of a given factor on the difference between the two models.

A2.3.3 Scenarios in the Participative Design of an Agent-Based Model Of Pesticide Diffusion (PHYLOU)[3]

A2.3.3.1 Introduction

Phylou is an agent-based model of pesticide diffusion on a sub basin of the Orb valley. It integrates different hypotheses about the size and distribution of the spots, the border of the spots and the management options of the farmers. The rules of decaying of the different pesticide molecules are included in the model, as well as the flow of water on the soil, ending in the river. The topology of the sub-basin is also taken into account in the model (for more details, see WP3 report).

A2.3.3.2 Use of scenarios in Phylou

In case of Phylou model, the scenarios include two different types of features:

- descriptors of different strategies of weeding and of different organizations of land use/landscape. These descriptors are mainly spatial characteristics. They constitute the inputs to the simulations. Many possibilities can thus be envisaged in order to be able to explore consequences of various configurations mixing them;

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[3] The work on this model is carried out by F. Cernesson, O. Barreteau and A.L. Borderelle in Cemagref Montpellier

- items describing driving forces. Only climate (rains) is considered here as the engine of pesticide transfer. Economic forces and regulations can of course modify the amount and nature of spread pesticides. We assumed they are fixed for the duration of one simulation (one year) and that the consequences of their actual evolution are taken in account through the diversity of possible behavioural patterns simulated. This time step of simulation lead us actually to put aside any macro aspect of scenarios. Aim is more exploration of consequences of potential patterns than evaluation.

Inputs of simulations which are constituting first part of scenarios are mainly based on (cf. table in Orb slides for Koblenz or in WP3 report):

- amount and decision criterion according to rain of spreading pesticides in plots (5 strategies are distinguished)
- spatial organization of vineyard (distance to the outlet)
- nature of plot borders : relative length and position of various possible natures of borders (grass, hedge, way, slope, ditch). Among those ditches (length, connexity and spatial configuration) have the main focus for transferer water (and pollution)
- topography and thus slopes
- presence of non-cultivated plots, nature and relative positions of these.

A2.3.3.3 One example

We consider the pollution level at the subcathment outlet as a function of the proportion of ditches among the edges.
Here, all the wine grower have got the same strategy for weeding.

Simulation corresponds to a given date.

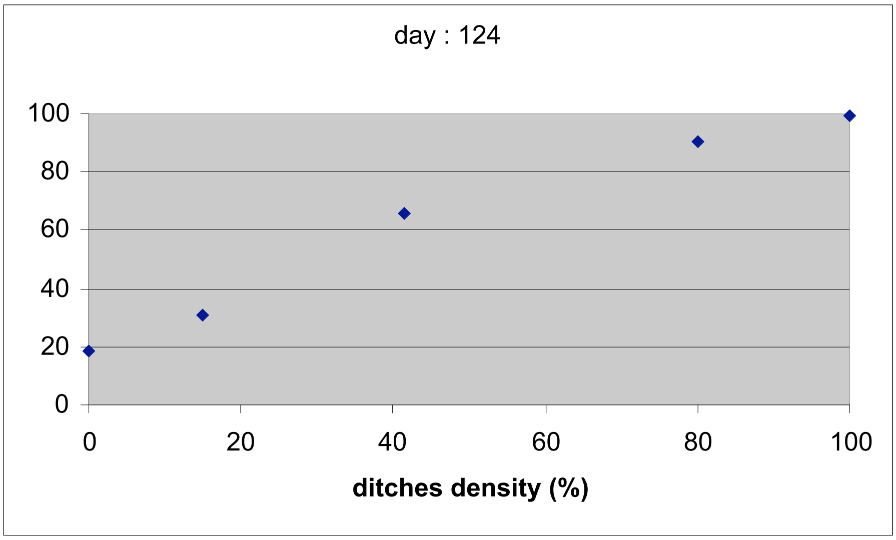

Figure A.2.3.1: *Ditch density*

The x-axis represents the proportion of ditches and the y-axis, the level of pollution at the subcathment outlet. The maximum level corresponds to the fact that the totality of the edges are ditches. The pollution level is expressed like a proportion of this maximum level.

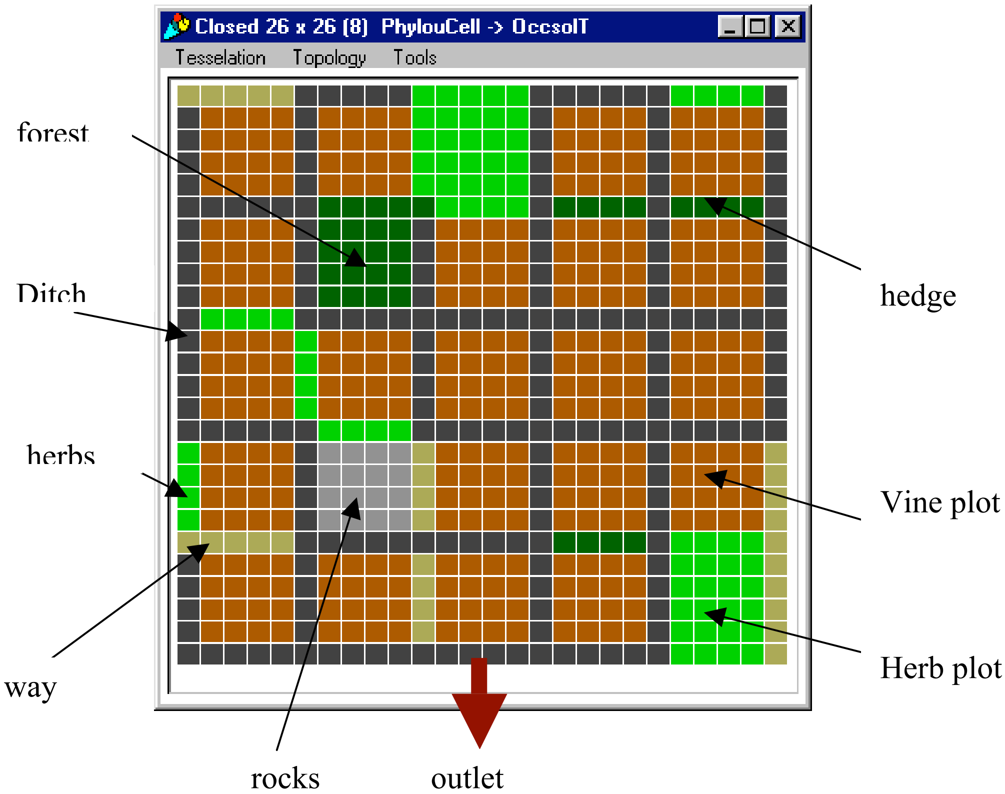

Figure A.2.3.2: *Representation of the subcatchment in the model, with different types of plots and edges.*

All these elements of scenarios have been chosen and discussed with a group of key stakeholders as explained in WP4 report. They have been validated through interviews with a set of wine growers (weeding practices) and are based on a landscape analysis.

One can note the questions put by the group to the sight of simulations:

- about modelling for communication (and validation questions)
- update of the assumptions of the model: for example, taking into account of the orientation of the vine, add process as infiltration to the water table…
- development of others scenarios, for example :
- other climate situations,
- choice of the molecule
- weeding by pesticides practices : dates, amount
- type of ditches : infiltration, transfer
- information exchange between winegrowers
- other landscapes

…

These reactions raised some methodological questions about the sampling, which we intend to investigate.

A2.3.4 Scenarios and Role Playing for a Participatory Decision Support System (SICOPTER)[4]

A2.3.4.1 Introduction

SICOPTER is a software which aims at helping a group of stakeholders to discuss and evaluate the result of a set of model on a set of scenarios (Rousseau et al. 2002). The main functionalities are: Spatial visualization of time series representing the results of the models (Bernard et al. 2001).

1. Evaluation of this result by each actors (for each value, acceptance, reject, no evaluation).
2. Publication of a set of evaluation, for each actors, representing a position that an actor wants to defend in the group (his viewpoint), at a given time.
3. Visualization of the viewpoint of the others actors.

[4] This work is carried out by L. Rousseau, S. Bernard and G. Deffuant in Cemagref Clermont-Ferrand

4. Comparison between viewpoints (are they agree or disagree, in which extend).
5. Visualization of comparison indicators.

We tested the approach iteratively with a group of experts from the Orb valley. The result of each test gave us indications for the goals of the next test. Our main goal is to test the capability of the software to increase the inter comprehension of the actors positions and finally to give some indication on:

1. A set of disagreements to leading to information search (such as a new simulation scenario).
2. A set of agreements to fund decisions.

A2.3.4.2 Description of Scenarios

The scenarios of water management are different dike building for over flood protection on a territory represented by a land covering scenario (that is land cover and land use). We bought the results of a hydrological model developed for the South of Bézier, in view of deciding the construction of dikes. The aim of these dikes was to offer various levels of protection to different small cities of the zone. However, the current debate being very sensitive, the company in charge of the software development and exploitation did not accept to give us the real result, but only slightly modified ones.

We used a second type of scenario: Role playing scenarios. The introduction of these scenarios in the process was necessary because the group of technicians who participated to the tests are not directly the stakeholders. They are civil servants in various administrations who often have to animate the processes of discussion about the management. Therefore, they have a very good knowledge of the behaviour of the real stakeholders. This is the reason why it appeared interesting to test the software with a role playing game, asking them to play the role of fictive stakeholders.

A role playing scenario is involves the description of several actors of the over flood protection negotiation in terms of activity, geographical localization and stakes. Each participant of the test had a role to play. Representing his role, each actor uses the software to build and exchange his viewpoint on each simulation scenario. The scenarios were built from different documents such as interviews with stakeholders and minutes of real discussion or negotiations. However, it is not required that they fit precisely real situations. We just need them to be plausible are the starting point of discussions or conflicts. The role playing scenario defined several roles like different majors, farmer (living in isolated habitation), a camping manager, several association (fishers, suburbs protection, ...) and an actor responsible of the application of the regulations. Each role was describe in terms of activity, stakes and localization. Each player received only his role, but they know the real case.

The land covering scenario of the simulation scenario is defined for the lower part of the basin from the city of Beziers to the Mediterranean sea. We retains three major zones. First, the south neighborhood of the city with recent suburbs on over flooded zones and some industrial risk on ecology. Second, a middle zone with isolated habitations and wine production. Finally, the coastal zone with camping and a sensible ecological area. Some smaller cities are disseminates on those three zones.

A2.3.4.3 Usability of the scenarios in our tests

The players are experts of this type of discussion. They were not involved in the real discussions but they precisely know the real case. They have immediately done the correspondence between the simulation scenarios and the real case. They matched their role with some real actors they know. So we can ensure that the scenarios are realistic. Face to our goal to test the capabilities of our software, the scenarios were needed to induce the conception of contrasting viewpoints. We already have proceed to two tests, and we are preparing a third.

***First test*.**

Before the first test, several presentations were made to the actors to explain the goals and potential utility of the software. Before the test session, we sent a paper describing the land covering scenario and a very short description of the role playing scenario to the actors. This description of the role playing scenario do not explain the stakes of the actors, but describe their activity. As a first test, we do not fix precise objectives, we just want to observe the players in their utilization of the software. A general observation guide was written for the researchers.

The session began with a presentation of the indicators on the model results, followed by a presentation of the land covering scenario. During this time, the players were manipulating the software tool. Three phases of utilization were foreseen:

1. Visualization of the simulation scenario data
2. Evaluation of this data
3. Comparison between the evaluations of the participants and discussion

Unfortunately, technical problem troubled the tests. We had to stop at the second phase. In addition of the technical difficulties, this session shown that the all scenarios were clearly understood by the participants.

Second test

Then, we organized a second test to complete the three phases. In addition, we improved the software by implementing some changes requested by the players. We completed the observation grid to follow the succession of the activities of each participant with the tool: visualization, evaluation and comparison steps. In front of each step, the researcher wrote free comments. We only changed the simulation scenarios, adding a full protection scenario for all the small towns. We did not have the results of the model for this scenario, so we applied local coefficient to the water levels and flows to take the modifications into account.

These session showed us that the software was technically ready. The first and second phase were accurately performed. The most important point concerned the third phase. First, the localizations of the different roles on the land cover were distinct, with very few intersection. Then, it happened that very few evaluations were done on the same localization and consequently, very few comparison were possible. In this test, it seems that the participants evaluate only his own localization. Second and probably linked to the first, we do not observe a real evolution of the evaluation in the direction of a consensus search.

Considering our objectives, we can ensure that:

- The visualization interface of the tool is accurate to represent the simulation scenarios.

- Using the tool help the participant to understand precisely the position of the other participants.
- These session do not meet the conditions to observe collaborative information search or collaborative decision making.

We can write several hypotheses about the last point to prepare the third forthcoming session. First, our prevision was that the comparison of the evaluations will permit such process. Then a modification of the role playing scenario could facilitate a globalization of the discussion. A second hypothesis that was not follow in this session concern the role of face to face steps during the session. In the conception of SICOPTER such face to face places take place between the comparison of a set of evaluations and a collaborative problem reformulation. In general, this reformulation is the expression of a lake of information such as a missing simulation scenario, data or actor. In our case, it is possible to begin the session with a restricted set of simulation scenario (the current state for example). Then, a discussion can take place before a first round to define the needs. Face to these needs, the facilitator propose a new set of simulation scenarios and the participants will use the tool for a new round.

Such succession and the way to implement it define a new type of scenario, the “animation scenario”.

Third test

The third test is not yet performed, it will take place in a few weeks. Our goal is no longer to test the use of the software by each participant, but the capability of the role playing scenario, the animation scenario and the software to facilitate the emergence of global discussion and information search. First, we have to modify the role playing scenario and particularly the localization of the activities of the roles. A potential way is to allocate each localization at a given major. Then, we should observe some intersection between evaluation permitting the use of evaluation comparison. Second, we have to define an animation scenario. It has to describe the sequence of the phases were the software is used and were the participants are face to face. For the phase of face to face, the animation scenario has to propose concrete objectives and ways to do. We can imagine to focus the discussion on the most desirable way for the flow, showing the consequences of a upper protection level for all used area. Another way can be to allocate priorities to each localization, depending the vulnerability of the activities. Our main local partner is a professional animator. We currently work with him to define this animation scenario. Third, the software has to be modify to include a “chat” module. Our communication module linked a textual commentary with a given evaluation. Then, the facilitator could not use it to organize its use.

A2.3.5 Conclusion

In conclusion, the importance of the scenario appears to be crucial in the test of such software. First, the situation has to be as realist as possible to ensure that the conclusions can be used. Naturally, the test of a new software cannot take place in a real situation, because of the uncertainty of its effect. Then, the usability role playing and simulation scenarios directly depends on their capability to appear realistic.

Our second session has clearly shown the importance of the animation scenario. This scenario defines the use of the software as a tool in a more global process. Then, it is crucial to judge the integration in the decision process and the interest of the software. These steps are necessary before envisaging the use of such tools in real negotiation processes, in order to make them more efficient and more democratic.

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A2.4 Scenarios Use and Development in the Thames Case Study

Cindy Warwick and Tom Downing

A2.4.1 Introduction

One of the main themes of work in the Southern England case study has been adaptation of water management systems to climate change. This has involved two different sections of work – an examination of household water demand and a questioning of the current drought management regime. Though these pieces of work differ quite substantially in some ways, the approach towards scenario use has been the same. In both cases, scenarios of climate change have been used as a procedural backdrop to agent activities. Agents interact with their circumstance (initial attributes and climate inputs over time) and with each other to make decisions that benefit themselves, their community or the wider world. Agent behaviours are not constrained to the realisation of a particular socio-economic scenario but create their own scenario based on rules of behaviour, initial conditions and driving forces. Using this approach the types of behaviours that lead to a certain scenario being realised can be explored.

This paper briefly describes the use of climate scenarios in the case study before discussing the agent-based social simulation (ABSS) scenarios and their use.

A2.4.2 The Use of Climate Scenarios

The case study ABSS focus on the potential impact of climate change on behaviours related to water supply and demand, particularly individual and institutional adaptation to drought risk and occurrence. The focus on drought occurrence and drought risk has come about due to the varying climate and hydrological conditions in the region as well as a recognition by regulatory agencies of the need to incorporate this into planning.

Scenarios of climate change in the UK are published by the UK Climate Impacts Programme (UKCIP) (see Hulme et al 2002). The climate change scenarios have been developed considering two main factors: the rate of green house gas emissions; and the response of the global climate to these emissions. Scenarios describing the rate of the green house gas emissions were selected from the IPCC Special Report on Emission Scenarios (SRES). The IPCC SRES scenarios provide possible storylines for the main drivers of green house gas emissions between 2000 and 2100. Emissions were then used as input to constrain the Hadley global climate model (GCM) of the atmosphere, including a dynamic ocean circulation model. This GCM is considered to be one of the best in the world. The climate sensitivity to the emission scenarios is generally estimated to range from 1.5 to 4.5 °C. The result of the UKCIP scenarios is a range of parameters related to global climate change.

The uncertainty of climate change is accounted for through the use of the scenarios and this sets a backdrop against which the appropriateness of management decisions can be seen and tested. In planning for drought, the possible depth and frequency of futures droughts must be considered. A common flaw in drought planning is preparing for droughts that have happened in the past as opposed to those that might happen in the future (U.S. Army Corps of Engineers, 1994). Climate change scenarios can help us to frame questions about possible future droughts and ABSS allows us to examine the dynamic between drought impacts and adaptations.

A2.4.3 ABSS Scenarios

With each run of the ABSS model, a new possible scenario of water demand is created. Similarly, each drought-game exercise will result in a new scenario of drought management. Table A2.4.1 presents the initial conditions, driving forces and outcome indicators of the ABSS scenarios.

Exercise	Initial Conditions	Driving Forces	Indicators/Outcomes
Household Demand	- Initial appliance list and OFV* values - Soil parameters - Overall Endorsement bias	- Introduction of new technology - Climate time series (leads to drought occurrence and messages from policy agent) - Endorsement of actions	- aggregate demand - uptake of new technology
Drought Game	- Drought plans - Roles - Initial indicator settings	- Climate time series (leads to drought event that must be managed) - links between climate and supply levels - supply-demand balance	- environmental indicator - social indicator - finance indicator - resource balance

* OFV = Ownership, Frequency, Volume of water-using appliances

Table A2.4.1: *Components of Simulation Scenarios*

From the initial conditions and randomness within the set-up and running of the simulation the programme (or gaming) agents, through their behaviours, develop a scenario in response to the driving forces. The outcomes are evaluated using the indicators given. Multiple runs, or games, are played to explore the balance between randomness and the impact of the initial conditions and driving forces.

A2.4.3.1 The Household Demand Model

In the case of the household model, the model is initially set to look at past situations, scenarios that have already occurred and for which we have indicator data. For this exercise, aggregate demand data was obtained from a water company. The simulation was then run with climate data for the supply area over the period of record. Initial OVF figures for the particular area at the simulation start time were estimated from national and regional averages. The validation of the simulation against the indicator data meant that different initial conditions and driving forces could be used to create new demand scenarios to be discussed and refined with stakeholders.

In the simulation, the agents do not have any foresight concerning where the system is going or the implications of their decisions. They are assigned values related to how much they will consider the self, local and global contexts of their actions. Agents cannot change these preferences over time but the decisions they make based on these preferences do change as their situations and available options change. As the options available and the endorsement weightings for each option change with every time step, agent behaviour is more than a simple reactive mechanism and behaviours can show adaptation over time.

The result of the ABSS is a scenario for aggregate demand under initial conditions and driving forces. The difference between this scenario for aggregate demand and other scenarios with the same output is that in this case one can understand how and why the demand is being generated. Behaviours can then be used to develop demand scenarios under different initial conditions and driving forces. The potential impact of changing behaviours on the aggregate demand pattern can also be explored.

A2.4.3.2 The Drought Game

In the drought game, the scenarios are created directly by the stakeholders. This is done within the context of the initial conditions and driving forces of the game.

As with the household demand model, the agents do not have foresight concerning where the system is going (when it will rain, how hot it will be, response to demand management exhortations, the behaviour of other agents etc.). However, agents do understand the general implications of their actions, can learn what to expect from the system and other players and can change their objectives or behaviours over the course of the game. In this exercise, the objectives are to manage the system effectively with respect to the resource balance and indicator levels but, more importantly, the goal of the game is to understand the actions, goals and limitations of the other agents, the uncertainties of the system and the appropriateness of organisational strategies and goals in working in the system. The scenarios that will result from game play, records of decisions and impacts on indicators and resource balance, are supplementary outcomes.

A2.4.4 Results and Discussion

In this case study, the use of the UKCIP climate change scenarios were used to reduce uncertainty in the problem space. The uncertainty of climate change has been studied and characterised in great depth and therefore it did not need to be revisited in this work. What is being examined in the ABSS scenarios is some of the uncertainty related to how individuals and organisations will adapt to climate change, namely in water demand and drought management.

In the household demand model, scenarios were used to examine how and why people responded to water saving messages. This was found to depend primarily upon the sourcing parameters and the arrangement of agents on the simulation grid. A secondary factor was the ability of an agent to save water depending, depending on their appliances and use patterns. When agents did respond to policy agent exhortations to save water, demand patterns generally approached pre-drought conditions as the memory co-efficient expired.

When developing ABSS within a scenario framework, care must be taken that there are no conflicts between the content and ideologies of the two scenarios. This has not been a significant problem in this case study as the individual interactions and water consumption behaviours described in the household consumption model are not dealt with in the UKCIP or IPCC SRES scenarios. In the drought game, the initial position and flexibility of water industry decisions may change under different scenarios but the game itself should not be in contact. As the game starts at present, this is not seen to be a problem.

In a computer model, once the agent behaviours are validated in known scenarios, the behaviours can be applied to different scenarios to understand possible responses and adaptations to different situations. In a gaming situation, understanding the perspectives, goals and behaviours of the other agents in an uncertain future is the key component of social learning. The understanding and validation of behaviours allows use to understand how and why scenarios could come to be and therefore what we may, or may not, be able to do to avoid, or work towards the realisation of, a particular scenario outcome.

A2.4.5 References

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A2.5 Zurich Case Study Scenarios

Matt Hare

A2.5.1 Use of Scenarios

Scenario analysis has been applied in the Zürich case study twice using two methods:

a) using paper models based on structure diagrams (see WP3, WP4).
b) using the role playing game (ZWG2) (see WP3, WP4)

The goals in both occasions were

a) Knowledge elicitation: to elicit more information from the stakeholders about the domain
b) Validation: to check with the stakeholders that the information in the scenarios is correct
c) Social learning: to encourage new learning about the consequences of water saving measures in the domain

A2.5.2 Scenarios Using Paper Structure Models.

A scenario was presented to the stakeholder group and worked through in the form of structure model (see Figure A2.5.1). Structure models categorise domain concepts into one of 9 categories:

- goals - what is to be achieved
- tests - how it can be determined whether a goal is achieved
- planning - how to achieve the goal
- context - under what external conditions must the goal be achieved
- norms - what the norms of the domain with respect to the goal are
- measures - how the plan is implemented
- results - what should happen if all goes well
- side effects - what might also happen
- communication - how might the goals and measures and results need to be communicated in support of the goal

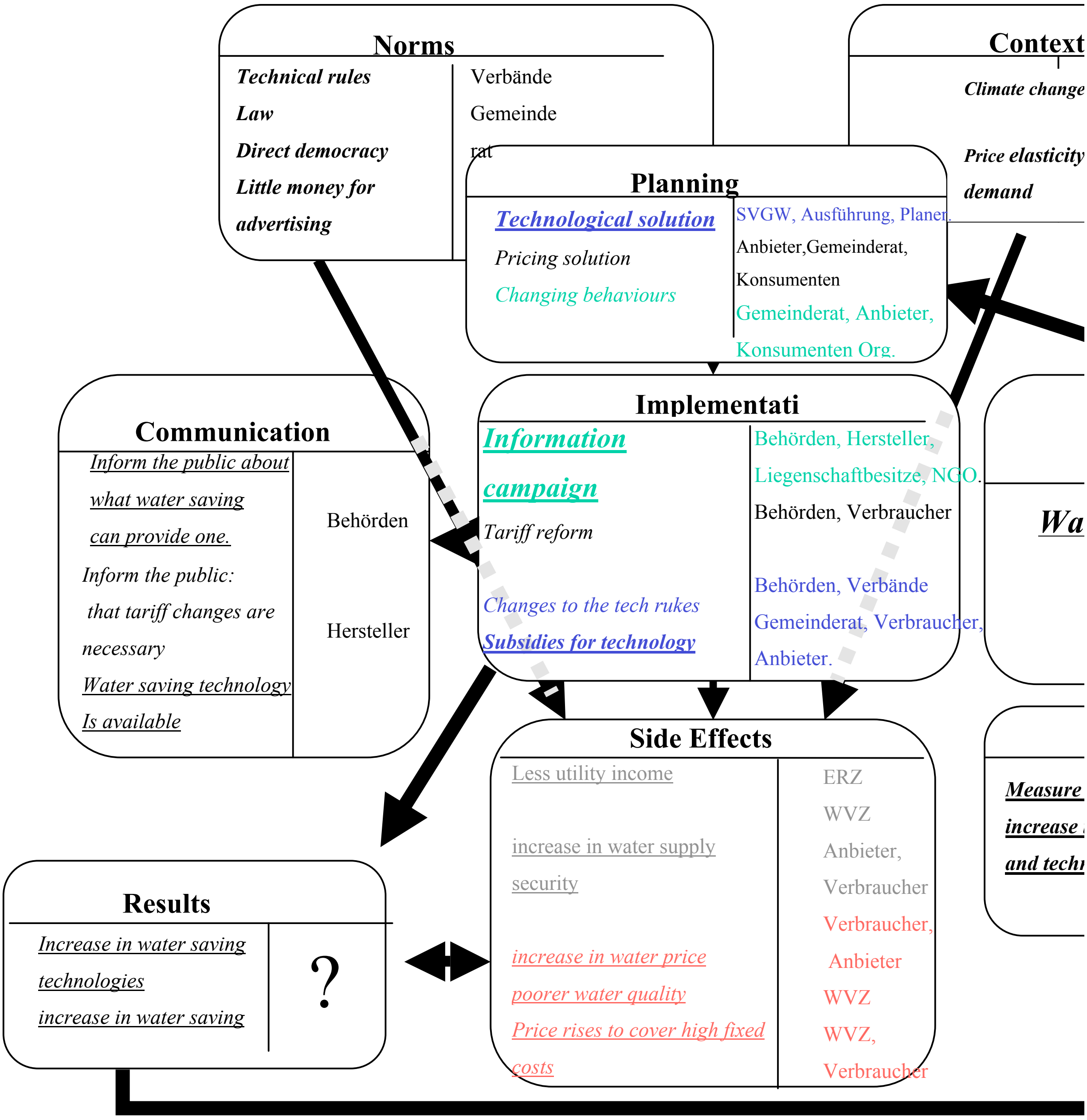

Figure 2.5.1: *Structure Model*

A2.5.2.1 Scenario: Water saving - possible methods and consequences

The structure model, based on the collation of knowledge elicited from individual interviews with the stakeholders (see WP4), investigated the probable methods of achieving water saving in the city and their possible consequences (Figure A2.5.1 "Structure model.ppt"). The manner in which it was presented allowed the scenario activity to take place. Essentially, the structure model was presented to the stakeholder group in the form of a causal narrative in which first goals, then planning, then measures and finally results and side effects were described. For example, the goal "water saving" was set. Then at the planning level the stakeholders had the choice of a technical, pricing or behaviour-based solution. Having chosen a technical solution (in Figure 2.5.1, selected options are underlined), given the context and the norms of the domain, the stakeholders were then presented with the possible measures that could be used to implement the plan. In this case, an information campaign allied to subsidies for the purchase or production of water saving technologies were selected. Relevant intended results would then include an increase in water saving technology in homes, and the increase in water saving. Side effects of these measures were then presented: less income for the water utilities due to water saving, increase in water price due to drop in income, increase in water supply security, and endangered water quality (since the water would be sitting in the pipes unconsumed for longer periods of time). New goals then might appear, such as the need to protect water quality, or the financial security of the water utility by increasing its efficiency (the goal of the second scenario).

During such a narrative cycle, the stakeholders are always providing feedback as to the validity of the scenario components. This naturally promotes much discussion among the group. Hence scenarios are constantly improved whilst the stakeholders share and learn knowledge about the different methods and positive and negative results of seeking to increase water saving.

A2.5.2.2. Outcomes

The outcomes of this scenario testing included an explanation of the water utilities ambivalent stance towards water saving. The fact is that the WVZ (the water utility) is not against water saving, but the problem is that the WVZ provides an infrastructure not just water and therefore water saving endangers finances since the fixed costs of this infrastructure are so high. There was then discussion about ways of financing the fixed costs in the face of decreasing demand e.g. a move to block charging for infrastructure, rather than charging simply for use, could help. The consumer association however, were against fixed charges, wanting to put meters in instead for the sake of fairness.

A2.5.3 Scenarios Using the Role Playing Game.

The board game version of the Zürich water game, was used to carry out policy analysis in the context of particular management scenarios. These scenarios were determined by the initial settings of the parameters for the water game. The parameters set were:

- popularity of politician
- quality of drinking water
- quality of lake water
- environmental awareness of public
- water demand of public
- water supply to public
- water price per unit
- demand as a function of environmental awareness and the type of water sanitation technology in households

By altering the initial values of these parameters, the stakeholders trying to manage the system in their various roles as water utility manager, politician, manufacturer of sanitation systems or housing association landlord, have to deal with different scenario dilemmas. The research team then take protocols (video and textual) to identify how they react and note any new criticisms of the underlying model that might arise. The stakeholders meanwhile discuss their problems and insights with each other during the game and hence social learning is encouraged about the best management practices with respect to different scenarios.

A2.5.3.1 Scenario: Over- capacity in an environmentally aware city

Parameter settings:

- popularity of politician = 5 (medium)
- quality of drinking water = 8 (high)
- quality of lake water = 8 (high)
- environmental awareness of public = 5 (medium)
- water demand of public = 60 (medium)
- water supply to public = 100 (high)
- water price per unit = 5 (low)
- demand/household lookup table:

	environmental awareness				
Sanitation system in house	1	2	4	4-6	7-10
normal	10	9	7	6	4
water saving	5	4	3	3	2

A2.5.3.2 Outcomes

In this scenario, there is an over capacity of supply at the same time as there being a private sector that is promoting water saving sanitation technologies to a public that have a reasonable level of environmental awareness. The main outcomes were that the players began to become more aware of the inter-connectivity and complexity of the relationship between the private and public sectors in the management system. Specifically, they discussed how the private sector promotion and purchasing of water saving technologies affects the financial security of the public water utilities. The public utility managers also discussed that their ability to manage this situation well depended heavily on whether or not the politicians, and both utilities could work together, since their ability to influence the private sector, individually, was limited. This confirmed to them the institutional inadequacy of the current, organisational split between the management of the water utility and that of the waste water utility. Additionally, new ideas about funding the water utilities in the face of over-capacity and increased water saving were considered. One suggestion was to channel value added tax from sales of water saving technologies to the utilities to help them service their fixed costs associated with a large water supply infrastructure that cannot be quickly reduced in the short or medium term.

APPENDIX 3. MODEL COMPARISON CHARTS

A3.1 Barcelona Case Study

Table A3.1.1. *Model comparison Barcelona case study*

Condition	Description	Participatory agent-based simulation
Model representations		
Natural systems	Link to physical and biological models	Agents perceive some social and physical features of the environment (temperatures, rainfalls, neighbous's consumption, etc) and react to emergency and draught situations
Social agents	Number of agents with social features (learning, imitation, etc)	Initial population are 10000 agents, although this number is endogenously changing (inmigration, borns and deaths). The agents are located on a grid where the different territorial units in the study area are represented.
Agent motivation	Conceptual model of agents, social theory	Agents have different influences from their own preferences: the water price, the neighbour's behaviour and the threat of emergency situations.
Societal structure	Relationships between agents or sectors; socio-economic change	Dynamic, structures and social groups evolve due to migratory models into the region in relation with the new territorial model.
Technology	Role of innovation and diffusion	Water saving technology can be introduced exogenously during the simulation. It can affect the agents or the efficiency of the hydrological net.
Resolution and scaling	Geographic and temporal resolution; scaling	Model represents a metropolitan area. Agents are placed on a grid, where the characteristic territorial units are represented. of the region and in each one of them is represented the household's proportion. The tick for temporal simulation is a month.
Validation	Model comparison against observed reality	Behaviour of the model population corresponds to observed profiles in territorial change and water demand, but we are working for finer-scale validation
Use/policy context		
Stakeholder participation	Model facilitates stakeholder participation	Stakeholders have identified the different relevant issues in the water demand, and those have been explicitly included in the model. A new review is going to be done forthcoming.
Hypothesis testing	Mode of model insight and approach to uncertainty	The main insight has been to show that the change of the territorial model of the region is one of the main causes of the actual water demand behaviour, as well as other behavioural and social causes.
Verification	Robust policy insight; cost-efficiency; reputation through peer review	Results are being reviewed by stakeholders currently.
Transparency	Access to assumptions that influence model results	Stakeholders can modify during simulation some of the main policy decisions. They also can setup the initial conditions previous to simulations.

A3.2 Maaswerken Case Study

Table A3.2.1. *Model comparison Maaswerken case study*

Condition	Description	Participatory agent-based simulation
Model representations		
Natural systems	Link to physical and biological models	Agents negotiate on the basis of their expectations for the future state of the river system given a river management strategy. Expectations are derived from a (bio-physical) Integrated River Model.
Social agents	Number of agents with social features (learning, imitation, etc)	6 agents are to be included in the negotiation model representing the following organizations or aggregated stakeholder groups: policy maker, citizen, nature organization, gravel extractor, farmer, and the Maaswerken planner.
Agent motivation	Conceptual model of agents, social theory	Stakeholder actions are based upon their beliefs and goals, which are fed by their perceptions of the environment and of other stakeholders, and by social norms
Societal structure	Relationships between agents or sectors; socio-economic change	Agents may cooperate to achieve mutual goals. Networks may change during negotiation
Technology	Role of innovation and diffusion	The Maaswerken project is innovative and new approach to river management and is a typical example of 'learning by doing'. Project planning therefore involves many uncertainties.
Resolution and scaling	Geographic and temporal resolution; scaling	The river system is schematised as a cross-section with a main channel and floodplain area representing a river engineering location. Agents do not have a specific geographical location. Typical time step for modelling negotiation is of the order of a month.
Validation	Model comparison against observed reality	Currently, data are lacking for thorough validation. Data will be obtained from simulations of the negotiation with representatives of stakeholder organisations.
Use/policy context		
Stakeholder participation	Model facilitates stakeholder participation	The model allows stakeholders to display their goals and perspectives on uncertainty and to understand what their preferred strategy would imply for other stakeholder, and is as such useful for communication. The use of the model as a planning tool for river management is experimental and would require policymakers and stakeholder to except uncertainties and adopt a more flexible planning process.
Hypothesis testing	Mode of model insight and approach to uncertainty	The method shows the bands of uncertainty in the estimations of impacts of river engineering measures. By coupling the uncertainties and different interests explicitly to stakeholder perspectives we clarify reasons for conflict and the implications thereof for the state of the river system on the long term.
Verification	Robust policy insight; cost-efficiency; reputation through peer review	The model is still in the development phase and a formal evaluation has not been conducted.
Transparency	Access to assumptions that influence model results	Assumptions underlying model calculations are made explicit in the form of uncertain model parameters (for the Integrated River Model) and in the form of priority ranking and threshold levels for satisfaction for the ABM.

A3.3 Orb Case Study

Table A3.3.1. *Model comparison for Orb case study, Comparing IBM and aggregate model*

Condition	Description	Participatory agent-based simulation
Model representations		
Natural systems	Link to physical and biological models	Agents see the state of the water resource, which is taken into account for their decision to use more or less water.
Social agents	Number of agents	10000 households (standing for ~77000 in reality) and ~750 farmers ; the basic water consumption corresponds to real data. Relationships are randomly picked between agents, once given a total number of relationships.
Agent motivation	Conceptual model of agents, social theory	The individuals choose between high or low water consumption relative to a basic water consumption. They are influenced by their actual behaviour, the behaviour of their neighbour and the state of the water resource ; the model is inspired by innovation diffusion and game theory.
Societal structure	Relationships between agents or sectors; socio-economic change	Behaviours evolve over time. No structural social change.
Technology	Role of innovation and diffusion	None here
Resolution and scaling	Geographic and temporal resolution; scaling	The model is designed at a small river-basin (Orb) scale (~120 000 water users). The time step is the month
Validation	Model comparison against observed reality	Real data are used for initialising water model, number of individuals and basic consumptions.
Use/policy context		
Stakeholder participation	Model facilitates stakeholder participation	
Hypothesis testing	Mode of model insight and approach to uncertainty	The purpose was to compare two models : individual-based and aggregate. Sometimes the results are similar : in this case the aggregate model is sufficient and faster. However it sometimes also fails to capture the complexity of the IBM.
Verification	Robust policy insight; cost-efficiency; reputation through peer review	Publication
Transparency	Access to assumptions that influence model results	

Table A.3.3.2: *Model comparison for ORB case study, Phylou model*

Condition	Description	Participatory agent-based simulation
Model representations		
Natural systems	Link to physical and biological models	Agents see the environment (react to previous rain and meteorological forecasts)
Social agents	Number of agents	a few tens of agents (depend on the landscape chosen). Each plot is linked to an agent (representing a farmer).
Agent motivation	Conceptual model of agents, social theory	5 various strategies of weed management
Societal structure	Relationships between agents or sectors; socio-economic change	indirect interactions (through environment in stage 1) co-ordination structures (cooperatives) in next stage.
Technology	Role of innovation and diffusion	pesticide spreading and mechanical work of land (as an alternative to pesticide spreading for weed management)
Resolution and scaling	Geographic and temporal resolution; scaling	model represents a slope of a virtual basin (roughly 30 ha). anamorphosis effect taken in account (diff scale for plots and borders) through dimensional analysis
Validation	Model comparison against observed reality	none have been done (but model has been done within a participatory process, including assumptions of representation of all parts of the system)
Use/policy context		
Stakeholder participation	Model facilitates stakeholder participation	interviews of actors and participatory modelling through a focus group composed of stakeholder at the managing level, and researchers. interviews of disciplinary experts for calibration
Hypothesis testing	Mode of model insight and approach to uncertainty	on going process
Verification	Robust policy insight; cost-efficiency; reputation through peer review	idem
Transparency	Access to assumptions that influence model results	participatory modelling process has made clear the assumptions
Additional categories added by case study		
Space agents		space interface is cellular automaton. Several landscapes (For the moment two are available) can be simulated. Both plots and borders are aggregates of cells. Number and size of plots depend on the choice of landscape simulated.
Passive Agents		pesticide molecules : 2 kinds of according to their solubility and degradation speed. Each agent is a standardized unit of pesticide (dose).
Dynamics		rain as an external driver. Each time step agents is acting or not for weed management. Each pesticide agent moves downward and is partially degraded

A3.4 Thames Case Study

Table A3.4.1.: *Model Comparison for the Thames case study*

Condition	Description	Participatory agent-based simulation
Model representations		
Natural systems	Link to physical and biological models	Agents do not see the environment but react to a policy agent that communicates drought risk and recommended water use
Social agents	Number of agents	100 agents sampled according to household size, ownership of water using appliances (based on company data), agents are located on grid (random distribution)
Agent motivation	Conceptual model of agents, social theory	Relative influence of their own demand for water, of policy agent's recommendation and of water usage by neighbours
Societal structure	Relationships between agents or sectors; socio-economic change	Behaviour changes over time in response to aggregated endorsements of water saving messages, but no structural social change
Technology	Role of innovation and diffusion	Water saving technology is introduced at various times, exogenous to agents' (i.e., no demand per se for technology)
Resolution and scaling	Geographic and temporal resolution; scaling	Model represents a sample of a water company region, which might have several million customers; while agents are placed on a grid, it does not correspond to an explicit spatial resolution—agents can 'see' neighbours in adjacent cells
Validation	Model comparison against observed reality	Behaviour of the model population corresponds to observed profiles of demand management, but data are lacking for finer-scale validation
Use/policy context		
Stakeholder participation	Model facilitates stakeholder participation	Stakeholders have reviewed the model but not the detailed behavioural assumption (e.g., wealthy households adoption of power showers); model will underpin drought contingency role playing in the project
Hypothesis testing	Mode of model insight and approach to uncertainty	The main insight has been to show that a wide variety of profiles of water demand are plausible, and particularly so with climate change—assumptions about behaviour are essential for demand management
Verification	Robust policy insight; cost-efficiency; reputation through peer review	A formal evaluation has not been conducted--results are being reviewed by stakeholders at present
Transparency	Access to assumptions that influence model results	While assumptions are explicit and easy to report, it is less clear that stakeholders understand their implications—particularly since the model is likely to be their first exposure to agent-based social simulation

A3.5 Zurich Case Study

Table A3.5.1. *Model Comparison for the Zurich case study**

** Note that the models referred to here are all based on a basic conceptual agent-based model (ZWG*) from which have been developed a simulation model (ZWG1) & a role playing game (ZWG2). Where no specific model incarnation is mentioned the explanation accounts for all three models.*

Condition	Description	Participatory agent-based simulation
Model representations		
Natural systems	Link to physical and biological models	Agents are aware of environmental indicators such as "drinking water quality" and "lake water quality". Their actions indirectly affect these indicators.
Social agents	Number of agents with social features (learning, imitation, etc)	Eight agents who can socially interact through negotiating the sales of household sanitary technology (housing associations and manufacturers) and negotiating support in the form of subsidies and activities (such as requesting the production of water saving technology.
Agent motivation	Conceptual model of agents, social theory	In ZWG1, heuristic rule-based teleological decision making aimed at maximising their individual indicators of success (e.g. wealth, water supply security, lake water quality, drinking water quality). Negotiation rules were elicited from real stakeholders whilst playing a role playing game version of this model (ZWG2).
Societal structure	Relationships between agents or sectors; socio-economic change	Agents can alter their views about who to negotiate with or support.
Technology	Role of innovation and diffusion	Diffusion of water saving household sanitation technology is prominent in this model. It partly determines the level of water demand and thus places constraints on the planning of the water utility agents. The degree of innovation depends on the demands for innovation by the non-manufacturer agents and the possibility for the manufacturers that money can be made by moving towards their production and promotion.
Resolution and scaling	Geographic and temporal resolution; scaling	The extent is a city. The resolution is at the level of organisations, not individuals. Housing associations represent 1000's of consumers.
Validation	Model comparison against observed reality	Basic model (ZWG*) validated by the stakeholders during the stages of model development and whilst they played the role playing game version (ZWG2). ZWG2 verified through playtests with and without stakeholders. Agents in ZWG1 only weakly validated, compared against "stylised facts" about the domain. ZWG1 being verified with sensitivity analysis using monte-carlo simulation techniques.

Table A3.5.1 *Model Comparison for the Zurich case study (continued)**

Use/policy context		
Stakeholder participation	Model facilitates stakeholder participation	Stakeholders had deep involvement in developing the model ZWG*, as well as in using it and validating it in its role playing version (ZWG2). Individual and group knowledge elicitation strategies were used to aid the gathering of stakeholder knowledge and meetings were used to get stakeholder feedback on the progress of the model and to the use the model as a focus for discussions on management. The stakeholders used the model in the form of the role playing game (ZWG2) which helped the stakeholders to identify with the model and learn about their own and others' roles in the complex management system. ZWG1was used to calibrate ZWG2 for use with stakeholders.
Hypothesis testing	Mode of model insight and approach to uncertainty	The role playing game (ZWG2) allowed the stakeholders to view, some for the first time, the complexity of the management system as a whole with all its component sectors. Uncertainty in management outcomes were highlighted by the realisation amongst the stakeholders that each stakeholder's decisions had an impact on each others leading to unexpected results of these decisions. More communication (formal and informal) between stakeholders was recommended as a solution to uncertainty and the inclusion of politicians and public in the use of such models.
Verification	Robust policy insight; cost-efficiency; reputation through peer review	Stakeholders reported that the use of the role playing game model (ZWG2) helped generate insight at an abstract level into complexities of decision making and to assist social learning. The model is not specifically detailed enough to provide robust policy insight.
Transparency	Access to assumptions that influence model results	Major assumptions were listed down and given to stakeholders to review. It is unclear whether or not the use of the model through role play-gaming (ZWG2) hindered stakeholders in challenging assumptions (since they might assume that they must obey the "rules of the game"). This has to be further researched. Evidence exists for both sides of the argument.