# An Electronic Institution for Simulating
# Water-Right Markets

Vicente Botti[1], Antonio Garrido[1], Juan A. Gimeno[1], Adriana Giret[1],
Francesc Igual[1], Pablo Noriega[2]

[1] DSIC, Department of Information Systems and Computation,
Universitat Politècnica de Valencia,
[2] IIIA, Artificial Intelligence Research Institute,
CSIC, Spanish Scientific Research Council,
{vbotti,agarridot,jgimeno,agiret,figual}@dsic.upv.es,
pablo@iiia.csic.es

**Abstract.** In countries like Spain, and particularly in its Mediterranean
coast, there is a high degree of public awareness of the main consequences
of the scarcity of water and the need of fostering efficient use of water
resources. Two new mechanisms for water management already under
way are: a heated debate on the need and feasibility of transferring wa-
ter from one basin to another, and, directly related to this proposal, the
regulation of *water banks*[1]. This paper is about *mWater*, an agent-based
electronic market of water rights. Our focus is on demand and, in par-
ticular, on the type of regulatory and market mechanisms that foster an
efficient use of water while preventing conflicts. In this work we present
the regulated environment which is implemented as an Electronic Institu-
tion for simulating water-right markets in order to evaluate the impacts
of different regulations on the market behaviour.

## 1   Introduction

Water scarcity is becoming a major concern in most countries, not only because
it threatens the economic viability of current agricultural practices, but because
it is likely to alter an already precarious balance among its many types of use:
human consumption, industrial use, energy production, recreation, etc. Under-
neath this emergent situation, the crude reality of conflict over water rights of
use and the need of accurate assessment of water needs and use become more
salient than ever.

   It has been sufficiently argued that more efficient uses of water may be
achieved within an institutional framework where water rights may be exchanged

---

[1] The 2001 Water Law of the National Hidrological Plan (NHP) —'Real Decreto
Legislativo 1/2001, BOE 176' (see www.boe.es/boe/dias/2001/07/24/pdfs/A26791-
26817.pdf, in Spanish)— and its amendment in 2005 regulates the power of right-
holders to engage in voluntary water transfers, and of basin authorities to setup
water markets, banks, and trading centers for the exchange of water rights in cases
of drought or other severe scarcity problems.

more freely, not only under exceptional conditions but on a day to day basis [3, 9, 12]. It has been claimed that if farmers cannot sell their extra water allotment, they have no incentive to use the allotment efficiently and it may become wasteful [5]. Moreover, a straightforward extension to other types of stakeholders would promote trading for non-irrigation uses, such as industrial uses, aquiculture, leisure or navigation, thus improving market conditions and hence efficiency of water use [3]. We propose to implement such a market with a regulated open multi-agent system, $mWater$, whose main features we discuss in this paper. Our focus is on demand and, in particular, on the type of regulatory and market mechanisms that foster an efficient use of water while preventing conflicts.

Considerable effort has been invested in the development of sophisticated basin simulation models and in improvement and innovation of water use practices. Literature abounds in examples of decision support systems for water management [8], sustainable planning of water volumes [2, 6], or the use of shared visions for negotiation and conflict resolution [7]. We explore an alternative approach in which individual and collective agents are an essential component because their behavior (and effects) may be influenced by policy-making. There are few projects along this line, but one may point to the NEGOWAT project (http://www.negowat.org/ingles/inicio/Inicio.htm), whose goal is to help negotiations between stakeholders in peri-urban catchment areas when water conflicts arise. Closer to our own approach, the recent effort is project MAELIA (http://www.iaai-maelia.eu), which involves simulation of socio-environmental impact of norms for water and other renewable natural resources and the environment.

We are interested in the institutional framework that simulates the "rules of the game" that may allow one to study the role that regulation, social environment, coordination, conflict resolution mechanisms, reputation or trust play in the decisions participating agents make and their aggregate results. Ideally, the institutional framework should add flexibility to current water use practices without increasing the number or complexity of disputes. To this end, we have designed $mWater$ as an agent-based system that simulates an electronic market of water rights in which we use agreement technologies such as: normative reasoning, negotiation rules, argumentation, trust, collective decision-making, social conventions, sanctioning mechanisms, as well as organizational and institutional environments preferences, among others.

The main goal of this paper is to describe the $mWater$ regulated environment that fosters efficient use of water resources by means of water-right transfer agreements (Section 2). We propose $mWater$ as our particular setting; nonetheless, it can be useful for other markets not related to water problems. In order to be more concise, Section 3 devises the simulation environment for this electronic market. Section 4 provides a particular case study on regulatory aspects in $mWater$, which again can be extrapolated to other domains. Finally, we conclude the paper with some remarks in Section 5.

## 2  An institutional framework for *mWater*

The *mWater* framework is rooted on traditional practices and regulations for the use and transfer of water rights that are either currently established by the Spanish National Hydrological Plan or are to be part of the forthcoming Basin Hydrological Plans. However, it is somewhat idealized in order to provide a richer sandbox for agreement technologies and a more malleable platform for demand and water use modeling and simulation in an hydrographic basin. The core component of *mWater* is an agent-based virtual market for water usage rights that intends to grasp the components of an electronic market where water rights are traded with flexibility and under different price-fixing mechanisms. In addition to trading proper, *mWater* also includes those activities that follow trading; namely, the agreement on a contract, the use and misuse of rights and the grievances and corrective actions taken therein. These ancillary activities are particularly prone to conflict albeit regulated through legal and social norms, and therefore a crucial objective in policy-making and a natural environment for agreement technologies.

For the construction of *mWater* we have followed the IIIA *Electronic Institution* (EI) conceptual model [1], whereas for the actual specification and implementation of *mWater* we use the EIDE platform². 

Procedural conventions in the *mWater* institution are specified through a nested performative structure (Fig. 1) with multiple processes. As seen in the figure, there are several roles: (i) guests, i.e. users before really entering the market; (ii) water users, i.e. the guests that have valid water rights; (iii) buyer/seller, thus representing the particular role the water user currently joins for the market; (iv) third parties, i.e. those water users that are direct or indirectly affected by a water transfer —usually conflicting parties; and (v) market facilitator and basin authority, thus representing the governing roles of the market. The top structure, *mWaterPS*, describes the overall market environment and includes other performative structures. *TradingHall* (Fig. 2) provides updated information about the market, and at the same time users and trading staff can initiate most trading and ancillary operations here. Finally, *TradingTables* establishes the trading procedures. An outline of their constitutive processes (performative structures and scene protocols) follows.

**Top structure, *mWaterPS*.** *Entitlement*. Only bona fide right-holders may trade water rights in the market and there are only two ways of becoming the owner of a right. Firstly when an existing right is legally acquired from its previous owner outside of *mWater* (through inheritance or pecuniary compensation for example). Secondly when a new right is created by the *mWater* authorities

---

² EIDE is a development environment for Electronic Institutions, built at the IIIA, http://e-institutor.iiia.csic.es/eide/pub. It is composed of a set of software tools that support all the stages of an Electronic Institution (EI) engineering, namely: 1) ISLANDER, a tool for EI specification; 2) aBUILDER, a tool to support the automatic generation of agent (code) skeletons from ISLANDER specifications of an EI; 3) the AMELI middleware that handles the enactment of the institution; and 4) SIMDEI, a testing and monitoring tool.
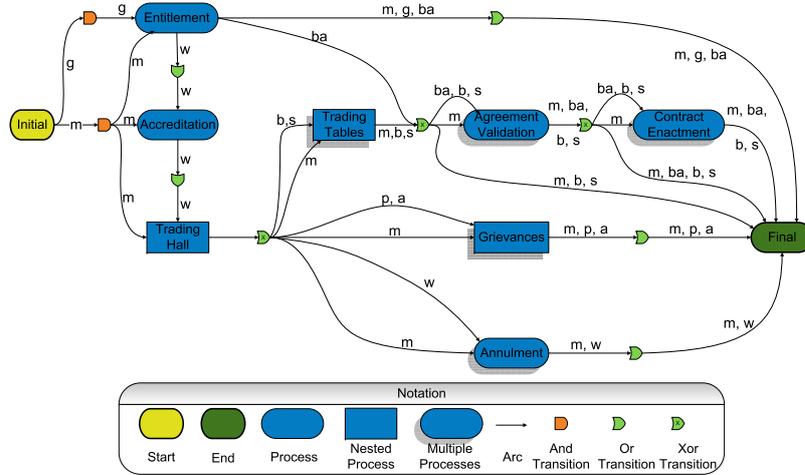
**Fig. 1.** *mWater* performative structure. Participating Roles: *g* - Guest, *w* - Water user, *b* - Buyer, *s* - Seller, *p* - Third Party, *m* - Market Facilitator, *ba* - Basin Authority

and an eligible holder claims it and gets it granted. *Entitlement* scene gives access to the market to new right holders who prove they are entitled to trade. It is also used to bootstrap the market.

*Accreditation.* This scene allows legally entitled right-holders to enter the market and trade by registering their rights and individual data for management and enforcement purposes. Staff have to validate admission conventions and right-holder variables are given default variables. When a right suspension is overridden or an agreement is void, rightful owners need to register again.

*Agreement Validation* and *Contract Enactment.* Once an agreement on transferring a water right has been reached, it is managed according to the market conventions. *mWater* staff check whether or not the agreement satisfies formal conditions and the hydrological plan normative conventions (*Agreement Validation* scene of Fig. 1). If the agreement complies with these, a transfer contract is agreed upon and signed by the parties involved in the *Contract Enactment* scene, and then the agreement becomes active.

*Annulment.* This scene in the *mWater* performative structure deals with anomalies that deserve a temporary or permanent withdrawal of rights.

**TradingHall performative structure.** Intuitively, in this complex performative structure, see Fig. 2, right-holders become aware of the market activity (*Open Trades* and *Ongoing Agreements* scenes), and initiate concurrent activities: get invitations to trade and/or initiate trading processes (*Recruiting* scene), initiate grievance procedures as described below in Fig. 3 (*Ongoing Agreements* scene), and get informed about anomalous situations, for example severe drought situations, (*Critical Situations* scene). Actual trading starts inside the *TradingHall* scene. On the one hand, updated information about existing trade-
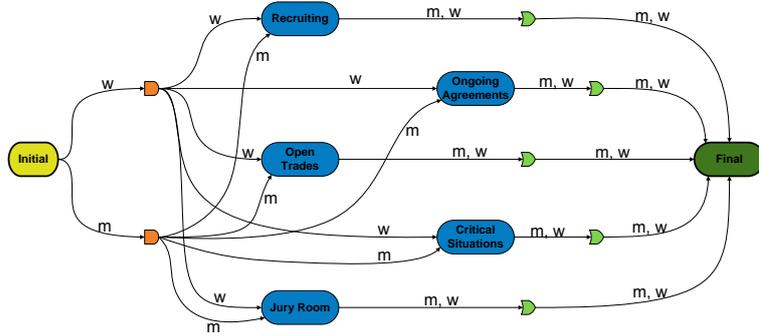
**Fig. 2.** *TradingHall* performative structure

able rights, as well as ongoing deals, active contracts and grievances is made available here to all participants. On the other, as shown in Fig. 2, users and trading staff can initiate most trading and ancillary operations here (from the *Recruiting* scene): open, request trading parties and enter a trading table; query about different agreements and initiate a grievance procedure from the *Ongoing Agreements* scene or, in the same scene, get informed about a dispute in which the water user is affected. Members of the Jury may also be required to mediate in a dispute at the *Jury Room* scene. Technically speaking, all these scenes are "stay-and-go" scenes: while the users are inside the market, they have to *stay* permanently in these scenes but they may also *go* (as *alteroids*, clone-like instantiations of the same agent that allow the agent to be active simultaneously in different scenes) to other trading table scenes and contract enactment scenes where they are involved: these scenes where user alteroids become involved are created (as a new *instance* of the corresponding performative structures) when a staff agent creates one at the request of a user, of an authority, or because of a pre-established convention (like weekly auctions).

*TradingTable* **performative structure.** In our *mWater* performative structure (recall Fig. 1), a market facilitator can open a new trading table whenever a new auction period starts (i.e. automatically) or whenever a right-holder requests to trade a right (i.e. on demand). In such a case, a right-holder chooses a negotiation protocol from a set of available ones (e.g., face to face negotiation, closed bids, standard double auction exchange or any others that are agreed upon). Consequently, in order to accommodate different trading mechanisms, we assemble the *TradingTable* performative structure as a list of different scenes, each corresponding to a valid trading mechanism or negotiation protocol. Each instance of a *Trading Table* scene is managed by a *Negotiation Table Manager*, *tm*, who knows the structure, specific data and management protocol of the given negotiation protocol. Among other negotiation mechanisms, we have included face-to-face, Dutch auction, English auction, standard double auction and blind double auction with mediator negotiation. Moreover, new negotia-
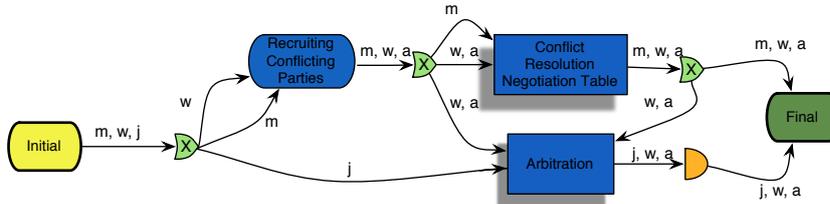
**Fig. 3.** Grievances performative structure

tion protocols may be easily added providing that the new protocol definition complies with the generic structure.

Every generic negotiation table is defined as a three-scene performative structure. The first scene is *Registration*, in which the *tm* applies a filtering process to assure that only valid water users can enter a given trading table (recall situations when a private trading table is being executed or only a sub-group of water users that fulfill a set of constraints may participate in the table). The specific filtering process will depend on the given negotiation protocol and possibly on domain specific features. The second scene is the negotiation protocol itself, in which the set of steps of the given protocol are specified. Finally, in the last scene, *Validation*, a set of closing activities are executed, for example registering the final deals, stating the following steps for the agreement settlement, verifying that the party that leaves the table satisfies the exit norms of the trading table, etc.

**Grievances.** Once an agreement is active, it may be executed by the new right-holder and, consequently, other right-holders and some external stakeholders may initiate a grievance procedure that may overturn or modify the transfer agreement. Even if there are no grievances that modify a contract, parties might not fulfill the contract properly and there might be some contract reparation actions. If things proceed smoothly, the right subsists until maturity.

Fig. 3 shows the different scenes of the complex Grievances performative structure. In this structure any conflict can be solved by means of two alternative processes (these processes are similar to those used in Alternative Dispute Resolutions and Online Dispute Resolutions [10, 11]). On the one hand, conflict resolution can be solved by means of negotiation tables (Conflict Resolution Negotiation Table performative structure). In this mechanism a negotiation table is created on demand whenever any water user wants to solve a conflict with other/s water user/s, negotiating with them with or without mediator. Such a negotiation table can use a different negotiation protocol, such as face to face, standard double auction, etc. On the other hand, arbitration mechanisms for conflict resolution can also be employed (Arbitration performative structure). In this last mechanism, a jury solves the conflict sanctioning the offenses.

There are three steps in the arbitration process. In the first one, the grievance is stated by the plaintive water user. In the second step, the different conflicting parties present their allegations to the jury. Finally, in the last step, the jury, after

14

hearing the dispute, passes a sentence on the conflict. The difference among the two mechanisms for conflict resolution is that the arbitration process is binding, meanwhile the negotiation is not. In this way, if any of the conflicting parties is not satisfied with the negotiation results he/she can activate an arbitration process in order to solve the conflict.
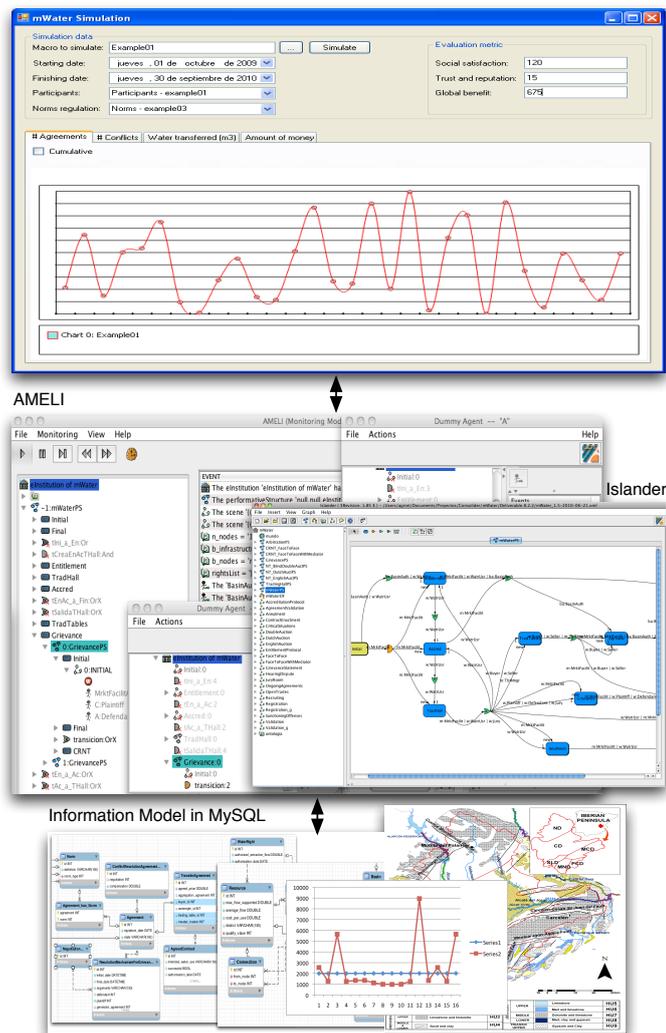


**Fig. 4.** *mWater* Simulation Environment

# 3 The *mWater* simulation environment

Fig. 4 depicts the overall structure of the *mWater* simulation environment. The interface of the simulation tool is simple and intuitive, in which the user can configure a given simulation with the following data: the starting and finishing date for the period to be simulated, the water users that will participate in the market (different groups/type of water users can lead to different results; consider for example a group in which some water users do not trust on other members of the group, this situation will probably result in a low number of agreements and a high number of conflicts), the regulation that will be applied in the simulation (in next section a case study example is presented with two different norm regulations applied to the same water user population and simulation period). The interface also provides graphical data that reflects how the market reacted to the input data in terms of the number of transfer agreements signed in the market (historical data including information about real or simulated users), volume of water transferred, number of conflicts generated, etc. Apart from these straightforward functions, other quantitative results are shown. These results are from a group of "social" functions in order to asses values such as the trust and reputation levels of the market, or degree of water user satisfaction, among others.

The central element in the simulation tool is the EI described in last section, that is specified in ISLANDER and executed in the AMELI runtime platform (recall Fig. 4). In order to start a simulation of the market, *mWater* feeds from an Information Model (implemented in MySQL) in which historical data from a given basin are registered. In this way, policy makers can simulate the market with real data from sever drought periods, rain spell, etc. depending on the starting and ending dates defined for the simulation. Moreover, the Information Model registers all the changes in the market in order to provide statistical data to the policy makers about the market behaviour for the simulated period, the water users that participated in the market, and the regulations selected for the particular simulation.

Note that we have mainly considered *mWater* as a simulation environment, but actually we are also interested in it as an open environment to human users for conducting social and participatory simulations. In such situations, human subjects take part in the simulation to see the effects of their interaction with virtual agents, applicable norms and their adaptation. This is part of our current work.

# 4 A case study simulation in *mWater*

The emphasis on regulatory aspects in *mWater* is motivated by the fact that the main objective policy makers have in mind is to achieve an adequate behavior of users. And regulation is the main tool that policy makers have to modify behavior. However, in practice, users are prone to achieve "order without law" [4], or at least to keep on adapting to regulations in order to preserve their

successful practices while policy makers keep on adapting regulations to guide users in a constantly changing environmental and political media. Thus, our *mWater* demonstrator provides the foundations for the study of that interplay. In order to show the way *mWater* can be used as a simulation tool for testing how regulations and norms can modify the users' behavior we show a simplified case study that mainly focuses on the interplay of norms and relaxes the other aspects in the market. In this case study, we test the user behavior when a single norm is modified. This scenario is related with the registration of transfer agreements.

In *mWater* we have three different types of regulations: (i) government laws, issued by the Spanish Ministry of Environment (stated in the National Hydrological Plan); (ii) basin or local norms, defined and regimented by the basin authorities; and (iii) social norms, stated by the members of a given user assembly and/or organization. The norms applied in this case study are currently defined in the NHP. However, policy makers have observed that only few water rights transfer agreements are registered in the basin while a lot of non-registered transfers are taking place by means of private commitments. This situation appears due to the interplay of the following norms:

*Government law - (N0)*: A water-user can use a given volume of water from a given extraction point, if and only if he/she owns the specific water-right or has a transfer agreement that endows him/her.

*Government law - (N1)*: Every water-right transfer agreement must be registered within the fifteen days after its signing and wait for the Basin Authorities' approval in order to be executed.

*Local norm - (N2)*: The registration process of a water-right transfer agreement is started voluntarily by the agreement signing parties.

*Social norm - (N3)*: Whenever a conflict appears, a water user can start a grievance procedure in order to solve it.

In order to include norm *N1* in the current EI implementation of *mWater* we have designed the *Agreement Validation* scene (see Fig. 1) as a successor scene for any Trading Table. When any water user enters this scene, the Market Facilitator verifies the constraint of fifteen days from the agreement statement process related to norm *N1*. If this constraint is satisfied the water-right transfer agreement is forwarded to the Basin Authority, who activates a Normative Reasoning process in order to approve, or not, the agreement, based on the basin normative regulation. If the agreement gets approved it is published in the Trading Hall in order for every water user of the basin to be informed of the transfer agreement.

On the other hand, norm *N2* is automatically included in the *mWater* institution due to the EIDE implementation feature by which no participating agent in the electronic institution can be forced to go to a given scene. For the particular *mWater* example, neither the buyer nor the seller can be forced to go through the transition between the Trading Table scene and the Agreement Validation scene (see Fig. 1). This way, whenever the buyer and/or the seller goes to the Agreement Validation scene he/she starts the scene voluntarily, so norm *N2* is satisfied.

The implementation of norm *N3* requires a specific performative structure, named *Grievances* (Fig. 3), in order to deal with conflict resolution processes.

Finally, the observance of norm compliance is delegated to every water user. Hence, the enforceability of norm *N0* is delegated to every water user.

The implementation described above is fully NHP-compliant, but it leads to a low number of transfer agreement registration and, moreover, to the following very critical situation for the reliable execution of *mWater*. Let us suppose there is a water user $A$ who has a water-right $w_1$ and wants to sell it. $A$ starts a Trading Table inside the *TradingTables* process (see Fig. 1) in order to sell $w_1$. The water user $B$ enters the Trading Table and as a result there is an agreement $Agr_1$ between $A$ and $B$, by which $B$ buys $w_1$ from $A$ for the period $[t_1, t_2]$, and pays the quantity $p_1$ for such a transfer. $A$ and $B$ belong to $Basin_x$, in which norms *N1*, *N2* and *N3* apply. $A$ and $B$ do not register $Agr_1$ due to norm *N2* (in other words, $A$ and $B$ do not go to the Agreement Validation scene of Fig. 1). Since there is no mechanism in $Basin_x$ by which water-right $w_1$ is blocked from $A$ after its selling (due to $Agr_1$ is not registered and $w_1$ is still owned by $A$ in time periods not overlapped with $[t_1, t_2]$), $A$ continues to operate in the market. Afterwards $A$ starts a new Trading Table to sell $w_1$ for period $[t_3, t_4]$, with $t_1 < t_3 < t_2$ and $t_4 > t_2$ (the new period $[t_3, t_4]$ is overlapped with $[t_1, t_2]$). In this second Trading Table $A$ and $C$ sign $Agr_2$, by which $A$ sells $w_1$ to $C$ for the period $[t_3, t_4]$ and $C$ pays $p_2$ to $A$. $A$ and $C$ belong to $Basin_x$. In this case $C$ registers $Agr_2$ in the *Agreement Validation* scene, due to *N1* and *N2*, and obtains the basin approval for executing $Agr_2$. At time $t_3$ (the transfer starting time) $C$ attempts to execute $Agr_2$, but there is no water in the water transportation node, since $B$ is also executing $Agr_1$. At this moment $C$ has a conflict with $B$, and in order to solve it he/she has to start a grievance procedure due to *N3*.

Although the previous described situation is critical, *mWater* can overcome it thanks to the Grievance performative structure. When $C$ cannot execute $Agr_2$ (because there is no water in the water transportation node), $C$ believes that $B$ is not complying norm *N0*. $C$ believes there is a conflict because $Agr_2$ endows him/her to use the water, and moreover, there is no transfer agreement published in the Trading Hall that endows $B$ to do the same. In order to enforce norm *N0* and to execute $Agr_2$, $C$ starts a grievance procedure. In this procedure, water users $C$ and $B$ are recruited as conflicting parties and $A$ as third party because he/she is the seller of $w_1$ as stated in $Agr_2$ (Recruiting Conflicting Parties scene of Fig. 3). Let us assume $C$ chooses as conflict resolution mechanism arbitration, because he/she does not want to negotiate with $B$. After stating the grievance, $C$ and $B$ present their allegations to the jury. In this process $B$ presents $Agr_1$ by which he/she believes there is fulfillment of norm *N0*. However, in the last step, by means of a Normative Reasoning function, the jury analyzes the presented allegations and the normative regulations of the basin and deduces that there is an offense. Both $B$ and $A$ do not conform with norm *N1*, and additionally, $A$ has sold the same water right twice within an overlapped time period. In this last step, the jury imposes the corresponding sanctions to $A$ and $B$.

**Table 1.** Market behaviour with varying regulations

| Regulation | Neg. Tables | Agreements | Water Volume | Conflicts | Periods |
|---|---|---|---|---|---|
| $\{N0, N1, N2, N3\}$ | 100 | 48,3 | 12.352 | 23,5 | 5 |
| $\{N0, N1, N2', N3\}$ | 100 | 25,6 | 3.521 | 6,2 | 5 |

*mWater* allows to simulate changes in the regulation in order to test what will happen, for example, if norm *N2* is replaced by norm *N2'*:

*mWater - Local norm - (N2')*: The registration process of a water-right transfer agreement is started automatically by the institution whenever a water-right transfer negotiation ends successfully.

Norm *N2'* is implemented directly in the Negotiation Table, allowing the Negotiation Table Manager to monitor all the negotiation protocol in order to detect the *Accept* message for a given bid. When the message is detected the Negotiation Table Manager informs the Basin Authority of the new agreement and it gets automatically published in the Trading Hall. In this way if the policy maker decides to include norm *N2'* as a regulation for the market in a given simulation the market participants that negotiated a successful agreement in a Negotiation Table go directly to Contract Enactment scene without going through Agreement Validation, and all the water user in the market get informed of the new agreement.

Recall in the previously described situation the first transfer agreement $Agr_1$. Norm *N2'* makes $Agr_1$ public just after the *Accept* message issued by $A$ or $B$ in the given Negotiation Table. In this way, when $A$ tries to open a new Trading Table to sell $w_1$ for the period $[t_3, t_4]$, the Market Facilitator verifies that the new period overlaps with the period associated in $Agr_1$ (that affects the same water right) and consequently rejects the request of $A$. In this way, norm *N2'* reduces the number of conflicts caused by second selling of the same water right.

In order to test the market behaviour with the different group of norm regulations described above, we executed various simulations in *mWater* varying the regulation and the simulated period (5 different periods) with the same group of water users. Table 1 shows the results of these evaluations. From this table, we can conclude that regulation $\{N0, N1, N2, N3\}$ leads to a higher number of agreements (Table 1 reflects both registered and non-registered agreements) and indeed a higher amount of water transferred. Unfortunately, the number of conflicts is also higher. On the other hand, $\{N0, N1, N2', N3\}$ leads to fewer agreements, not only because the water-rights cannot be re-sold any more, but because not all the water users wanted to participate in the market due to the obligation to make public all the transfer agreements[3]. In order to evaluate other type of market reactions to regulation changes we are now working on "social"

---

[3] This situation happens in Spanish basins, and it was deliberately included in the agent behaviour of the water user participants in order to observe its effects on the market.

functions in order to asses values such as the trust and reputation levels of the market, or degree of water user satisfaction, among others. We believe that this type of measures will provide the policy makers with valuable data for decision making about new or modified regulations.

## 5  Conclusions and Future Work

As a whole, *mWater* constitutes a rather sophisticated regulated open multi-agent system. It is designed with three objectives in mind. First, as a demonstrator in the AT project (www.agreement-technologies.org), it provides a testing environment and inspiring problem domain for conceptual proposals and tools. Second, it may be used as the demand component of a sophisticated basin model to simulate, visualize and explore different water management policies, users and norms. That is, it helps explore the interactions between the basin hydrographic resources and infrastructures, together with the use of water as it is being modulated by market mechanisms and policy directives and regulations. Third, given the possibility of the creation of an actual market for water rights or analogous public goods, *mWater* would be a first proof of concept version to build upon.

The work we report in this paper provides insights on the regulated environment of *mWater* as an Electronic Institution for simulating water-rights markets. We are now developing a richer normative regulation in order to allow to simulate different types and group of norms. We are also working on defining performance measures that can evaluate 'social" issues in the market behaviour. At the same time we are developing different populations of water users in order to simulate varying type of members in a basin and to observe what are the effects of a given regulation when different type of water users are interacting the market.

## Acknowledgements

## References

1. J. Arcos, M. Esteva, P. Noriega, J. Rodriguez-Aguilar, and C. Sierra. Engineering open environments with electronic institutions. *Engineering Applications of Artificial Intelligence*, (18):191–204, 2005.
2. X. Cai, L. Lasdon, and A.M. Michelsen. Group decision making in water resources planning using multiple objective analysis. *Journal of Water Resources Planning and Management*, 130(1):4–14, 2004.
3. J. Calatrava. Mercados y bancos de agua en España. *Agricultura Familiar en España*, pages 99–105, 2006.

4. R. C. Ellickson. *Order without law : How neighbors settle disputes*. Harvard University Press, Cambridge, Mass. :, 1991.

5. J. Honey-Roses. Assessing the potential of water trading in Spain. In *ENR 319 Advanced International Environmental Economics. Professor Theo Panayotou at Harvard's John F. Kennedy School of Government*, 2007.

6. F. Martin de Santa Olalla, A. Dominguez, F. Ortega, A. Artigao, and C. Fabeiro. Bayesian networks in planning a large aquifer in Eastern Mancha, Spain. *Environmental Modelling and Software*, 22:1089–1100, 2007.

7. R.N. Palmer, W.J. Werick, A. MacEwan, and A.W Woods. Modeling water resources opportunities, challenges and trade-offs: The use of shared vision modeling for negotiation and conflict resolution. In *Proc. of the Water Resources Planning and Management Conference*, 1999.

8. V. Rajasekaram and K.D.W. Nandalal. Decision support system for reservoir water management conflict resolution. *Journal of Water Resources Planning and Management*, pages 410–419, 2005.

9. L. Riesgo and J.A. Gomez-Limon. Mercados del agua. analisis de las opciones elegidas para su aplicacion en España. In *Proc. of the IV Congreso Nacional de Economía Agraria*, 2004.

10. T. Schultz, G. Kaufmann-Kohler, D. Langer, and V. Bonnet. Online dispute resolution: The state of the art and the issues. In *Available at SSRN: http://ssrn.com/abstarct=899079*.

11. W.K. Slate. Online dispute resolution: Click here to settle your dispute. *Dispute Resolution Journal*, 56(4):8–14, 2002.

12. M. Thobani. Formal water markets: Why, when and how to introduce tradable water rights. *The World Bank Research Observer*, 12(2):161–179, 1997.