

A role-playing game to support multi-stakeholder negotiations related to water allocation in South Africa: first applications and potential developments

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ABSTRACT

The new South African water law (NWA, 1998) provides a framework for the implementation of a largely decentralized and participatory approach to water resource management. New organisations (the Catchment management agencies - CMAs, and the Water users associations - WUAs) are being established to ensure that water allocation among users at the catchment level will follow the principles of economic efficiency, social equity, and environmental sustainability, as indicated in the National Water Resource Strategy (NWRS – DWAF, 2002).

To achieve this, CMAs and WUAs will have to put in place processes of participatory decision-making and facilitate negotiation among water users having different socio-economic characteristics, unequal access to information and knowledge, and therefore a different capacity with regard to lobbying and negotiation.

A role-playing game was developed to contribute to the process of building the capacity of groups of stakeholders to understand and design their own negotiation process, selecting decision-making criteria for their own catchment. The game uses as inputs, among others, annual production costs, prices of water licences, economic value of in-stream water, and generates consequent outputs in terms of financial impacts, environmental impacts (effects on the ecological reserve) and social impacts (equity in water supply) of different water allocation strategies.

The paper describes the main features of the role-playing game, shows the outcomes of its first tests, and discusses the potential uses of the tool.

Key words: Role-playing game, water management, negotiation, post-normal science, action research, simulation tool.

1 INTRODUCTION

South African water policy based on the National Water Act (1998) provides a framework for the implementation of a decentralized and participatory approach to water management. The new act is radically different from previous water legislation, particularly with regards to water rights. Under the new NWA, water is considered a public resource. Only the right of use -and not ownership- is granted to users, through a licensing system for which they are required to pay. Another major feature of the NWA is decentralisation of water management through the establishment of catchment level water management organizations such as Catchment Management Agencies (CMAs) and Water Users' Associations (WUAs). Finally, protective

measures have been introduced to secure water allocation for basic human needs and ecological and development purposes¹ (Farolfi and Perret, 2002).

Social development, economic growth, ecological integrity and equal access to water remain key objectives of the new water resource management legislation. The above-mentioned institutions are currently being established at regional and local level, emphasizing a largely decentralized and participatory approach to water resource management.

The National Water Resource Strategy (NWRS) is the implementation strategy for the NWA. It provides the legal framework for the future management of water resources in South Africa (DWAF, 2002). The main objective of the NWRS is to match and balance water demand with water supply, in accordance with the sustainability, equity and efficiency objectives of the NWA.

The implementation of the Act and the NWRS raises many social questions and economic uncertainties, within a context of water scarcity, profusion of users and uses, backlogs and inequalities in infrastructure and water supply (Perret, 2002). In this context, it is believed that one of the key roles of CMAs is the regulation and control of water demand.

The approach set up for this purpose is the allocation of water use authorisations to users. A licensing process is therefore necessary. Issues and difficulties arising from this process include prioritising licensing between different uses and users, timing and methodology for the renewal of licenses and the potential impact of certain licensing strategies. In other words, there is a clear need for tools that can help the future decentralised water management organizations to accomplish their complex tasks.

Moreover, CMAs will have to put in place processes of participatory decision-making and facilitate negotiation among water users having different socio-economic characteristics, unequal access to information and knowledge, and therefore a different capacity for lobbying and negotiation.

Role-playing games (RPG) are increasingly adopted for educational purposes as well as for dealing with negotiation issues (Barreateau, 2003).

A RPG was developed to contribute to the process of building the capacity of groups of stakeholders to understand and design their own negotiation process, selecting decision-making criteria for their own catchment.

After a presentation of the background to the game (2), aimed at recalling the nature of this RPG derived from a simulation model, this paper provides an illustration of the main features of the RPG (3), the phases and timing of a game session (4), some outcomes of a test session (5), and draws some conclusions (6) indicating the perspectives of utilisation for this tool and discussing its limits and usefulness in training and information/negotiation-support contexts.

2 BACKGROUND TO THE GAME

The RPG is derived from a simulation model (Farolfi and Hassan, 2003) called AWARE (Action research and Watershed Analysis for Resource & Economic sustainability). This model aims at investigating the economic efficiency, environmental sustainability and social desirability of some of the water management strategies that CMAs could potentially use. AWARE looks at situations whereby once established, CMAs would handle the licensing processes. It is a prospective

¹ According to the NWA, the Reserve is a portion of the water resource in each catchment that falls under the national responsibility of the Minister of Water Affairs and includes the following components: the ecological reserve, and the human component to satisfy "basic human needs". The ecological reserve, as specified in DWAF-IWQS (2002), p. 15, is "the quantity and quality of water required in a basin to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource". Basic human needs are defined in chapter 3, part 3, of the National Water Act as an amount of water corresponding to 25 l/person/day (NWA, 1998).

simulation-oriented tool representing the perspectives and behaviour of public agencies and individual water users. The Steelpoort sub basin of the Olifants river catchment, shared between the Provinces of Limpopo and Mpumalanga was selected as study area because of its complete representation of the major sectors of water use as well as the availability of data.

The model was originally conceived as a multi-agent system (MAS) (Bousquet *et al.* 1998). The most recent version of AWARE is a simulation model constructed in a programming language specifically designed for system dynamics modelling (SDM) (Radzicki, 1997; Richmond, 2001).

According to Barreteau (2003) the relationships between RPG and computerized models can be represented through a conceptual scheme composed by the triplet {conceptual model, controlled experiment, observed reality}. Within this framework, policy exercises as the AWARE RPG would be anchored more in observed reality and less in the controlled experiment, for there is less control and resorting to the model, which is only an interface to help players' interactions. Barreteau proposes a typology of relationships between RPG and computerized model. It is based on the following keys: parts of the shared conceptual model and concomitance of use. Like the famous "Fish banks" (Meadows and Meadows, 1993), the AWARE RPG is used concomitantly with the computerized model and the latter is based on a conceptual model that is simpler than the RPG and with a limited extension. In other terms, making use of a simpler model that stresses the economic and environmental consequences of water allocation at the catchment's level, the AWARE RPG allows for a better representation of complexity and uncertainty in the behavior of players, institutional issues and environmental dynamics.

3 FEATURES OF THE GAME

In order to make the game "playable", the scale initially adopted for the model AWARE (The Steelpoort sub-basin) was reduced to a smaller virtual watershed (100 Km²), where a limited number of water users compete over a period of 10 years for the use of a scarce resource.

The focus is on the compulsory but difficult arbitration between economic efficiency, environmental sustainability and social equity, as criteria put forward by the NWRS. The role of the CMA as an entity for decentralised decision-making and negotiation-facilitating among competing stakeholders is stressed.

As economic (monetary) indicators were chosen to quantify the RPG outcomes, in-stream and off-stream values of water were considered, the latter being represented by the economic output of the water used by players that compete in the simulated watershed. In-stream income comes from fishing activities of the assumed 1000 rural households living in the area. This income added to the indirect value of the reserve (i.e. the value of its environmental services) provides an estimation of the total economic value of the water reserve (i.e. the total in-stream value) (Turpie, 2000).

The RPG goal is to cumulate at the end of the game the highest possible economic output (in-stream plus off-stream) coming from water.

The conceptual model underlying the RPG assumes that each player will try to maximize his/her profit (but playing the game players could refute this assumption), whilst CMA will play the role of negotiating-facilitator among stakeholders and decision-maker. It will propose and discuss a range of possible allocation strategies with all the players allowing public participation and finally will decide the policy to be implemented in order to achieve the difficult goal of preserving the ecological requirements assuring at the same time the most equitable and efficient distribution of the resource among stakeholders.

The criteria that allow ranking players' performance at the end of the game are illustrated in the paper annexure.

The players

Four groups of economic agents exist: smallholding farmers, large commercial farmers organised in an irrigation board (IB), industries and mines. Up to three agents of each sector, for a total of 12 players, can be included in the game. A single player or a team of players can impersonate each agent. This allows for the participation of a larger number of players to the game. The RPG operator takes the role of the CMA during the first stages of the game, and then a volunteer player may substitute him after several stages.

Players resources, initial state, and production choices

Players start the game with a quantity of water allocated that determines their present level of production. The relation between water used and production is characteristic of each sector and is made available at the beginning of the game². Players can choose to change the quantity of production, modifying the quantity of water used. They can also change their technology or farming practice. If they are farmers, they can choose between irrigated or dry agriculture. If they manage an industry or a mining site, they can choose between a standard technology and a water-saving one.

Gross revenues, costs, and relative profits change according to the choice made. Revenues and cost functions³ are also available for each player.

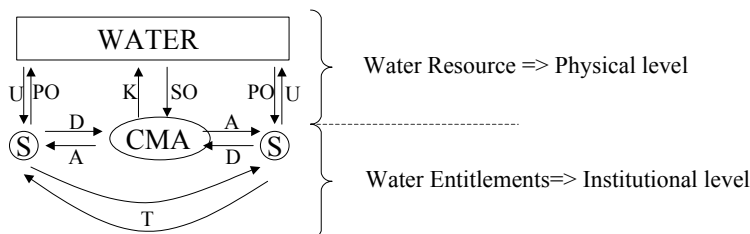
Water allocation and water entitlements demand⁴

The CMA determines every 3 years a water allocation strategy. According to this strategy, each sector benefits from an annual quantity of water entitlements, and

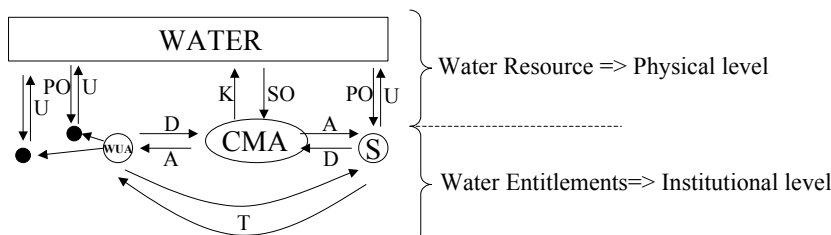
² All players use water as a factor of production. The relation between water and production is a function of the type: $Q = aw^b$, $0 < b < 1$, where: Q = annual production (in Tons), w = water use (in m^3), a and b are parameters defined on the basis of hypothesis made on the productivity of water for the different sectors, as well as on the basis of direct surveys (Myburgh, 2004). The shape of the curves allows considering the law of diminishing returns.

³ Total annual cost functions $TC(w)$ are linear and based on our hypothesis. Farmers choosing dry agriculture will have a fixed amount of annual production and a fixed total annual cost.

⁴ The relation between water entitlements (also called here water rights or licences) and physical water can be shown as in the following schemes, where it is pointed out that the CMA proposes a water allocation strategy (A) on the basis of a knowledge (K) of the availability of the resource. Then, stakeholders' (S)' water demand (D) and possible trade (T) is on licences (or rights/entitlements), while the use (U) of physical water brings private outcomes (PO) and social outcomes (SO) in terms of in-stream and off-stream values of the resource. Social outcomes are here represented flowing to the CMA as the representative of the whole community of the catchment.



If the entities that negotiate water entitlements allocations with the CMA are water users associations (WUA), the previous scheme may be adapted as in the following figure. The symbol (•) represents then individual users that receive water entitlements from the WUA. It might be noted that in real contexts entitlements trade may take place even among individual users (•), and that water entitlements allocation by the WUA is agreed by all WUA members and is contained in a "business plan" document.



pays a unitary price for water. If a particularly dry season threatens water resources in the basin, the CMA can decide unilaterally to reduce these entitlements.

Each year, every player addresses a demand for water rights to the CMA. This demand can be formulated individually or negotiated with the other players of the same sector. For the IB, this negotiation is compulsory. The water rights demand can correspond to the water effectively used by the player, but it can also be higher, if the player decides to sell a share of its rights to other players. In any case, the sum of water entitlements demanded by a sector cannot be higher than the water allocated to this sector by the CMA (water allocation strategy).

Water licenses trade among players

Players can exchange water licenses with other sectors. No intra-sectoral exchange is possible after the annual demand is addressed to CMA.

Water licenses trade occurs when one player willing to increase its water entitlements approaches another player willing to sell a share of his/her water licenses. A negotiation on the price of water rights and on the duration of the transfer is therefore established.

The duration of the transfer of right cannot be longer than the number of years remaining up to the next allocation strategy by the CMA, and in any case cannot exceed three years.

Other decision factors

During the 10 years of the game, several parameters can change and influence players' choices. These parameters are economic, such as the market price of their production, they can also depend upon the water management strategy (level of the reserve and consequent level of water allocable to economic activities, price of water decided by CMA), they can finally reflect the uncertainty of the environmental dynamics (the level of total water available can increase or decrease, affecting the availability of water for economic purposes).

4 PLAYING THE GAME

Players dispose of a decision sheet, where they capture their annual choices regarding water entitlements demand, the possible trade of water licenses with players of other sectors, and their choice on production technology.

Every simulated year, the game operator receives the decision sheets filled by each player and captures players' decisions to the computer, where the simulation model produces the outcomes (results).

The economic results of players' choices, together with the state of the resource, and the CMA strategies are made available yearly to each player through an annual report. Meanwhile, every outcome is visible at any time to all players through a data projector that projects to a large screen computer's outcomes.

Annual reports and decision sheets have the form presented in figure 1, while figure 2 shows how the RPG interfaces look on the computer screen. As an example, it is shown how the game operator reaches through the main control board the input capturing board and a plotted output (annual production) for the industrial sector.

Game steps

Every simulated year, all players impersonating economic agents perform the following tasks:

1. Receive the result from the computer (annual report)
2. Negotiate with CMA quantities, duration of water license transfer, and price
3. Make their choice regarding water entitlements demand, and their consequent production level

4. Decide if and how much water to buy from (or sell to) other players
5. Decide whether or not a water-saving technology is to be adopted
6. Fill the decision sheet and give it to the computer operator

Every three years, CMA decides a new water allocation strategy and water-pricing policy: a negotiation involving all water users, and CMA is launched. It aims at facilitating a participatory approach in the decision-making process of resource allocation. At the beginning of every year, CMA calls for a public discussion (cf. point 2 above) where the three-year water allocation strategy is recapped and, in the case of extraordinary events (e.g. sudden and serious drought), modified.

Timing

Ideally the RPG should be played over two days, the first day being dedicated to the welcome, briefing and game sessions, whereas the second day (half day) is for debriefing and group discussion.

A detailed timing includes the following schedule (11 hours in total):

Day 1

0.0 - 1.5 hours - Briefing

1.5 - 2.0 hours - Break (coffee, discussion)

2.0 - 4.0 hours - Game session 1 (repeating 5 times the steps indicated above: 1 to 5 years)

4.0 - 5.0 hours - Break (lunch, discussion)

5.0 - 7.0 hours - Game session 2 (repeating 5 times the steps indicated above: 6 to 10 years)

Day 2

0.0 - 1.5 hours - Debriefing

1.5 - 2.0 hours - Break (coffee, discussion)

2.0 - 4.0 hours - Group discussion

5 OUTCOMES OF THE GAME

The outcomes illustrated here come from a test session organized in November 2003 at University of Pretoria. 7 players took part to the session that was facilitated by 2 resource persons, of which one operated the computer, and the other played the role of the CMA for the first three years, then a volunteer player substituted her, which supervised and facilitated the game.

Players were university staff members and students from various disciplines (economics, sociology, hydrology, political sciences), research managers and officers from the Water Research Commission.

The following economic agents were interpreted in the session: 2 large farmers organized in an Irrigation Board, 2 smallholding farmers, one industry and one mine. For practical reasons the timing of the RPG was reduced to a 6-hour session (from 9:00 to 15:00) organised as follows:

Briefing: 9:00-10:30

Game: 10:30-12:30 (5 full years)

Debriefing: 12:30-13:00

Discussion (during lunch): 13:00-15:00

To avoid confusion and useless complications, the RPG facilitators decided to change overtime only two categories of exogenous factors and to allow water licenses trade among stakeholders only from year 3 onwards.

Because focus is on management of water resources and negotiation among users when water becomes scarce, the main exogenous factor changing overtime was represented by the available water in the catchment (that reduced from 6 million m³ at year 0 to 2 million m³ at year 4) as indicated in table 1. The other category of exogenous factors changing overtime is merely economic and is represented by the selling price of the hypothetical product of each sector.

Five full years were simulated, corresponding to a half complete game session. This limited of course the interpretation of the trends and behaviours observed during the RPG implementation. Nevertheless, playing the game generated big discussions among the players and between them and the game facilitators. The following main trends resulting from the game session were produced by the computer model that ran the simulations and provided a copious material for the debriefing and the group discussion at the end of the day.

Water availability, allocations, reserve, and CMA revenue

During the first three years, CMA went for an allocation strategy that preserved the reserve (figure 3). This limited water entitlements, but for the first three years water availability remained fair. At year 4 and 5 players had to face an important reduction of water availability, and CMA opted for a strategy that sacrificed part of the reserve and satisfied water users. This also increased the CMA revenue derived from licenses payment by users. Water trade among sectors was made possible from year 3, but it never represented a large share of the total water allocated (up to about 10%).

Economic outcomes for the catchment

The annual benefits' trends of water allocated to productive activities (figure 4) were strongly influenced by industry's and mine's trends. Therefore, they depended upon the market prices of these sectors assumed to decrease in year 3 and 4 according to the exogenous factors (table 1). In-stream value of the reserve reduced after year 3 as a result of the mentioned change of strategy by CMA.

Economic agents' trends

Smallholders adopted a strategy based on the use of the whole water allocated to them (no water trade, no dry agriculture). Their performances show that their choice was economically right (they showed the best performance criteria at the end of the game, as indicated in table 2). They were helped in that by two main factors: a) a good market price trend for their products; and b) a CMA's policy keeping the water price for smallholders at a very low level and guaranteeing for this sector a water allocation unchanged over the whole period.

In view of the important reduction of water entitlements to the Irrigation Board, the two *large commercial farmers* part of the IB adopted very different strategies. One of them (IB1) "sacrificed" his entitlements transferring them at zero price to the other commercial farmer (IB2) who could so maintain a decent level of production and made good profits overtime (figure 5). It was observable here a communal strategy of the two players belonging to the IB aimed at facing a drastic and quick resource scarcity. IB1 also sold part of his entitlements to mines and industries at year 3 and 5.

Industry's economic performance was heavily influenced by the market price of its products. Industry water demand did not seem to be limited by the higher water price determined by CMA overtime (rigidity of the demand). At year 5 industry decided to sell more than 50% of its entitlements to the mining sector, and still showed a very good economic performance that year, because of the favourable market price for its products after two consecutive bad years.

Mine adopted since year 2 a water-saving technology (probably worried about forecasts on water availability). This choice was not sufficient to avoid to be

penalised by the CMA allocation strategy, which reduced mine's water entitlements progressively and by 25% at year 4 with respect to the initial supply. The mining site therefore looked for water trade from year 3, when, although "water market" was open, few players were willing to sell water (no one was willing to do so at year 4). It therefore suffered particularly (worst performance this year). At year 5 it bought water licences from all other sectors in order to maintain a water supply in line with the previous years. This, in addition to a favourable market price for mining products this year, boosted mine's annual profit for the final year of the RPG.

As a result of the five years of game, the performance indicators illustrated in table 2 proved the two smallholders right in terms of economic strategies (and well protected by the CMA water entitlement strategy), whereas mines and industries were penalised both by the CMA water allocation strategy and the market trends. Large-scale farmers had very different performances, due to the mentioned communal strategy within the IB, which aimed at favouring the economic outcome of one farmer, sacrificing totally the other one. CMA strategy aimed at sacrificing part of the Reserve when water became scarce did not seem to reach brilliant results at the end of the period, particularly in terms of in-stream water income.

6 CONCLUSIONS, DISCUSSION AND PERSPECTIVES

The RPG presented is an information and communication tool developed from a simulation model (AWARE) that analyses possible water allocation strategies at the catchment level in the present South African socio-economic and institutional context.

Barreteau (2003) categorizes RPG encountered in science and development processes into two main families, differentiated by the point of view concerning the aim of the process: as a learning tool for the game organizers or a learning tool for the players. The latter family is then split into three types of uses: training, research and policymaking.

According to this categorization, the AWARE RPG can be considered as a learning tool for the players, mainly used for training and policymaking.

Nevertheless, the same author states that both types of learning (for the players and for game organizers) are not exclusive. In the case of AWARE, by playing the illustrated session players learned about the complex process of water allocation and the potential consequences of several allocation strategies, whereas researchers learned about players' behavior and discovered some unexpected dynamics of the game.

The participatory process of "learning by doing" (Liu, 1994) or "social learning" (Röling, 1994; Allen, 2000) that results from a RPG session refers to current trends in social sciences, with particular reference to Action Research (Dick and Dalmau, 1999; Allen, 2000; Farolfi, 2004).

Another important issue treated by using a RPG to build-up social knowledge about decentralized water management is uncertainty that results from complex systems' dynamics. Uncertainty leads to consider top-down oriented decision-support tools less useful than negotiation-support and discussion-facilitating tools as RPG in the management of natural resources. Post-normal science (Funtowicz et al. 1999) is the modern scientific paradigm that stresses the importance of dealing with uncertain realities where stakes are high, and the consequent need of putting in place processes of discussion, empowering and negotiation among stakeholders in order to facilitate governance (Ostrom, 1990) and participatory bottom-up management processes.

Following post-normal and participatory action-research approaches, the RPG AWARE seems to be suitable for adoption within two different contexts: a) training

sessions, mainly for public water managers; and b) information/negotiation sessions with real stakeholders.

As a training tool for decision makers (e.g. CMAs)

The scope of using AWARE as a training tool consists of showing the complexity that arises when different stakeholders interact dynamically for the use of a (limited) resource.

This complexity has several components, namely social (groups of stakeholders with different objectives, values, information, lobbying capacity, adaptive behaviour), environmental (water availability is influenced by climatic aleas, uncertainty, and depends on the use of the resource by stakeholders) and economic (economic strategies are different among stakeholders, even within the same sector). Moreover, exogenous factors (market trends, international political and economic context) may affect local economic systems such as a watershed. "Systems that are complex are not merely complicated; by their nature they involve deep uncertainties and a plurality of legitimate perspectives. Hence the methodologies of traditional laboratory-based science are of restricted effectiveness in this new policy context" (Funtowicz et al. 1999). In addition, complexity determines the emergence of trends and results that cannot be estimated or foreseen through the analysis of individual components of the system.

SDM such as the simulation model AWARE can provide a framework for the analysis of long-term trends in complex systems. Nevertheless, the scenarios produced by a SDM can account for only a very small share of the entire complexity that characterizes a socio-environmental system like a watershed where multiple stakeholders operate. The shift from the SDM AWARE to the RPG based on the SDM constitutes a change of perspective in the analysis of the water allocation problem at a watershed scale. In fact, running the game, decision-makers impersonate different stakeholders and the local water managing organization. They try to defend their individual and sectoral interests, being conscious of the importance of in-stream water and therefore of the use of the resource for purposes other than the strict economic activities.

The processes of decision and negotiation that take place yearly are complex and show the multiple components (psychological, sociological, economic, moral, etc.) that can influence and orientate the debates among stakeholders, as well as the decision on the use of the resource.

These processes cannot be shown by the model, but emerge clearly by running the game underlined by the model. The learning point for decision-makers is the difference between the adoption of a decision support tool (the model) and a negotiation support tool (the game). The top-down process of decision-making resulting from the use of the SDM without involving the local stakeholders in the process does not allow for the consideration of the multiple stakes, and, more importantly, does not emphasize the complexity and the consequent uncertainty resulting from social and environmental interactions of an even extremely simplified system like the one represented by the RPG.

Playing the game is likely to push the decision makers to think about complexity and uncertainty, and to foster processes of negotiation among stakeholders. Players are exposed to the risks connected with a top-down decision making process (e.g. lower satisfaction of stakeholders, lower assessment of complexity and therefore lower effectiveness, efficiency, and equity in decision making), and can better appreciate the importance of governance processes, participatory action, and negotiated strategies for the use of a limited resource such as water.

As an information vehicle and negotiation support tool for real stakeholders

Using the RPG AWARE in a context of a real negotiation process for the use of a limited water resource has the main advantage to provide a common framework of

knowledge and information regarding the processes deriving from water allocation to all the stakeholders (more precisely their representatives) of a specific watershed. Focus here is not on the results and the figures that are obtained running the game⁵, but on the dynamic processes that take place among groups of stakeholders, between them and the public authority, and within the environmental and socio-economic systems.

The awareness and knowledge by all water users of these multiple and interactive processes represents a clear example of local stakeholders' empowerment.

Asymmetry of information is among the major causes of unequal, ineffective, inefficient, and environmentally unsustainable water allocation among different users. By gathering for the duration of a full game session all stakeholders' representatives in the same context that simulates the reality of water management, and forcing them to face the difficulties of a negotiation process that aims at a common objective, the game contributes to rise questions, stimulate discussions, and fosters an exchange of ideas and knowledge that reduces this asymmetry of information.

Practical applications of the AWARE RPG in both proposed uses are scheduled starting from 2004. It will serve as a training tool within international training courses for water managers on environmental flows organized by the Centre for Environmental Economics and Policy in Africa (CEEPA) and as a negotiation-support tool within a Water Research Commission funded project in the Kat River, a sub-basin located in the Eastern Cape Province of South Africa.

A certain number of limitations and disadvantages were identified before, during and after the test session of the RPG.

Some of them derive from a limited knowledge of the empirical data and the functions that allow representing properly the social, economic and environmental impacts of water allocation strategies and the in-stream and off-stream resource values. Researchers will address these disadvantages in future versions of the tool.

Other limitations are structural and not likely to be improved in the future. The main structural limitation of the RPG consists in not being able to include in a game session a number of players larger than 30-35. This is due to the fact that a maximum of 12 economic agents and one CMA are the stakeholders represented in the RPG and, to avoid confusion and time losses during a session, the number of players composing a team that plays the role of one stakeholder should not exceed 3 (one in the presented test session). Thus, widespread display of the game will be limited and, especially for negotiation-support purposes, this fact implies the need to invite to the game session only representatives of the different groups of stakeholders involved, or alternatively to repeat the game several times. Other structural limits include not considering groundwater and water quality issues. In watersheds where these issues are crucial, there may be problems in adopting the RPG for information/negotiation-support purposes.

ACKNOWLEDGMENTS

The work was conducted under the project "Tools and Methodologies for the Sustainable Establishment of Decentralised Water Management Institutions in South Africa (CMAs)"⁶. This project, currently in its second phase (2004-2006), started in 2002 and is co-funded by the French Ministry of Foreign Affairs and the South African National Research Foundation. It is co-managed by the Centre for Environmental Economics and Policy in Africa (CEEPA) and the Centre for International Co-operation in Agronomic Research for Development (CIRAD).

⁵ These figures would in fact be reliable only if a previous work of data collection and analysis on the specific area where the game is played was realised. This work is seldom possible, particularly considering the time constraints related to the action research projects that involve the adoption of the game.

⁶ See details of the project at the web site: <http://www.ceepa.co.za/cma.html>

The authors gratefully acknowledge the inputs to the RPG development made by K. Pietersen, A. Turton, I. Naiker, C. Mitchell, S. Ntshingila and S. Yokwe.

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Economic Agents											
	0	1	2	3	4	5	6	7	8	9	10
ANNUAL REPORT: YEAR	10										
Production	1 000	1 000									
Selling price	4 924										
Annual profit + capital interests	4 924										
Cumulated profit	5 000										
Water licensed	0.0153										
Price water licensed	0										
Water bought from other sectors	0										
Cost of water bought	0										
Water sold to other sectors	0										
Revenue of water sold	0										
DECISION SHEET	0	1	2	3	4	5	6	7	8	9	
Demand for water licences											
Water used											
Water bought from sector a											
Price											
Water bought from sector b											
Price											
Water bought from sector c											
Price											
Water sold to sector a											
Price											
Water sold to sector b											
Price											
Water sold to sector c											
Price											
Innovation Y/N											

CMA											
	0	1	2	3	4	5	6	7	8	9	10
ANNUAL REPORT: YEAR	4 000 000	4 000 000									
Total water	1 695 000										
Reserve	2 305 000										
Entitled water	37 127										
CMA revenue	0										
Demand water not used by sector entitled	19 414 374										
Offstream benefits	7 198 665										
Instream benefits	26 613 039										
Total benefits											
DECISION SHEET	0	1	2	3	4	5	6	7	8	9	
Water allocated to smallholders											
Price											
Water allocated to IB											
Price											
Water allocated to industries											
Price											
Water allocated to mines											
Price											

Figure 1 – Annual report and decision sheet for an economic agent and for the CMA

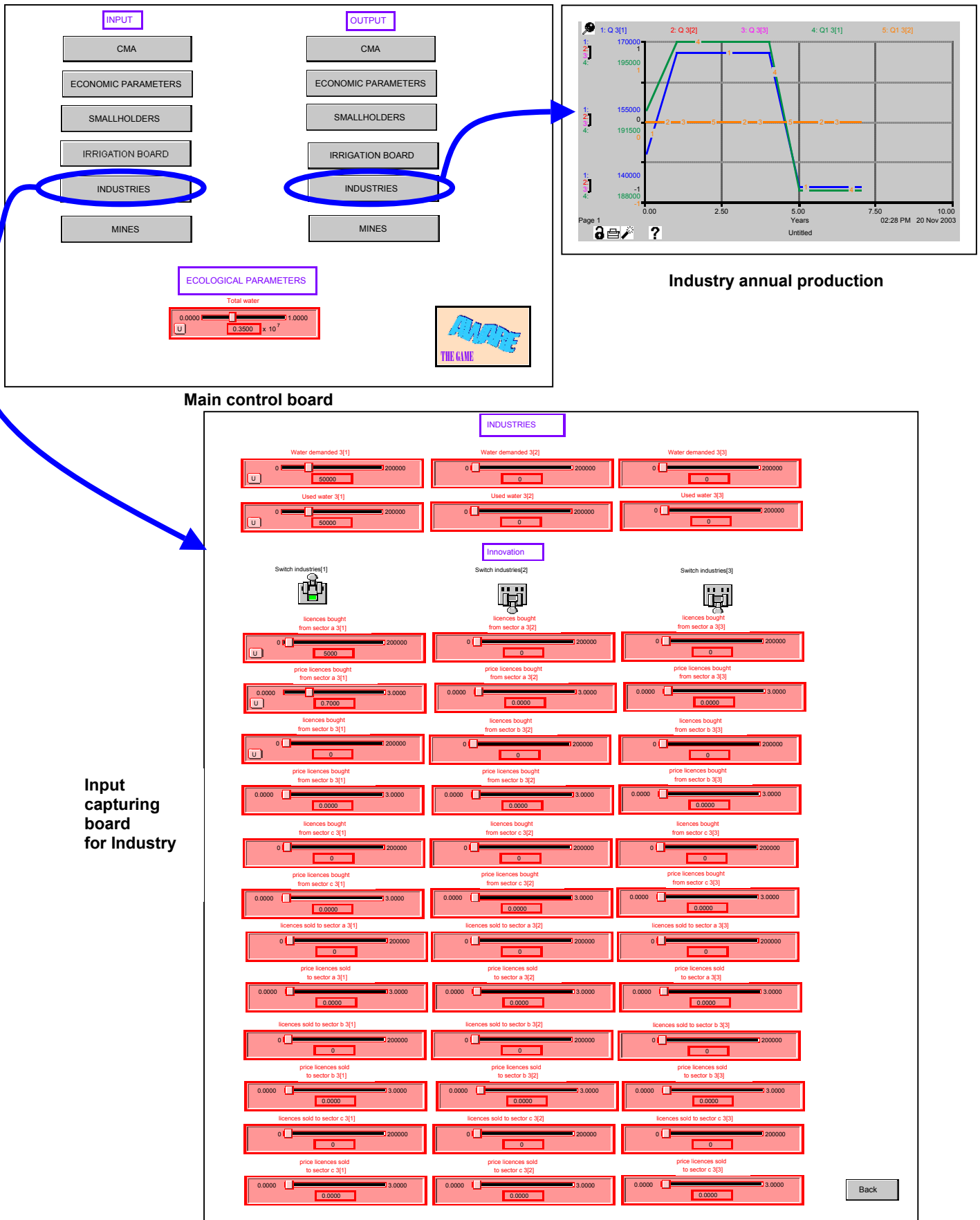


Figure 2 – The AWARE RPG computer interfaces for the game operator

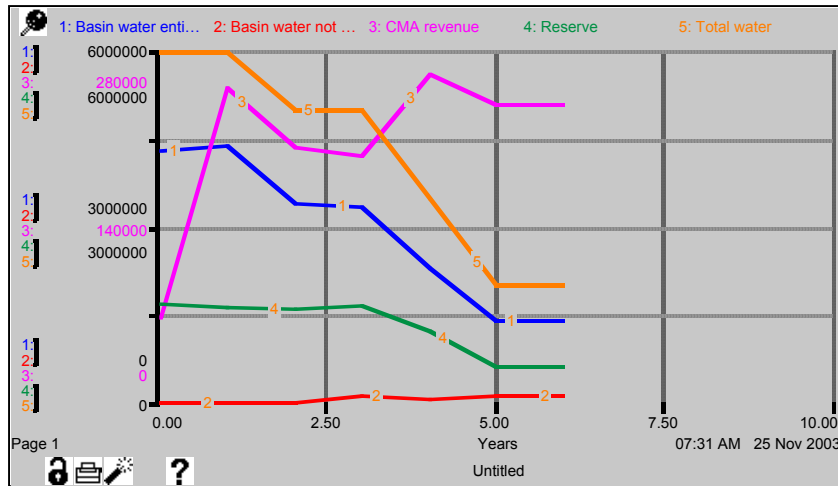


Figure 3 – Economic and environmental outcomes at the catchment level (CMA revenue in Rand; all other variables in m^3)

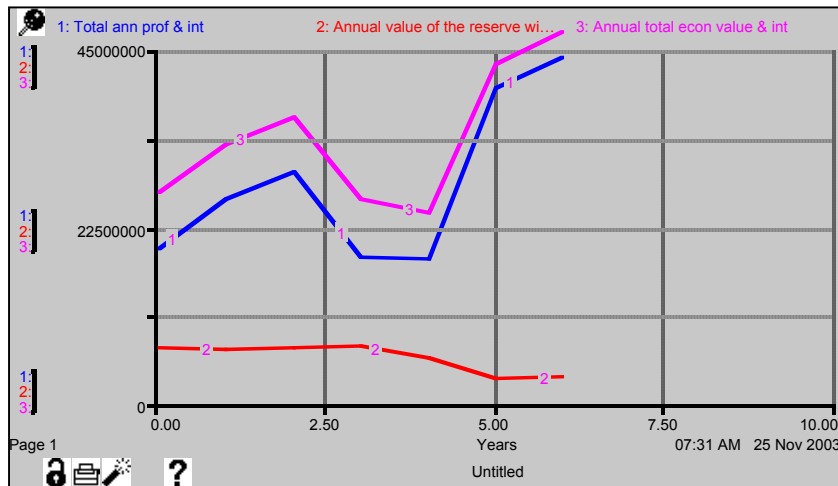


Figure 4 – In-stream and off-stream values of water at the catchment level (in Rand)

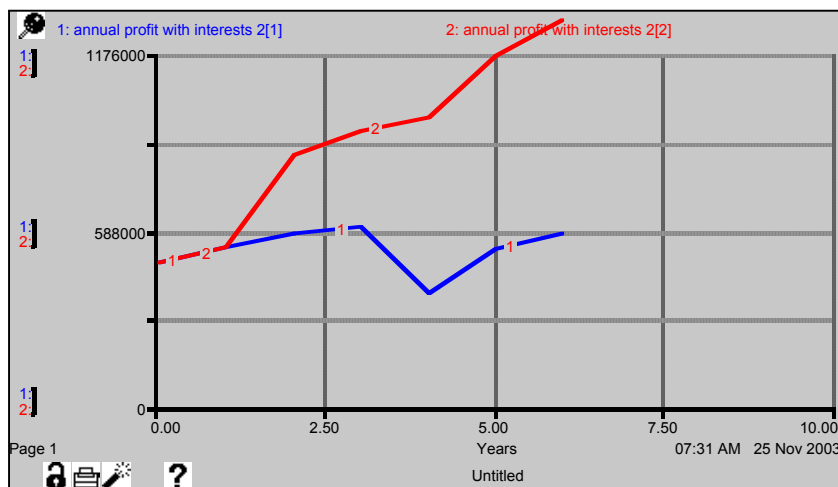


Figure 5 – Annual profit including interests for the two commercial farmers of the Irrigation Board (in Rand)

Factor \ YEAR	0	1	2	3	4
<i>Available water (000 m³/year)</i>	6,000	5,000	5,000	3,500	2,000
<i>Selling Price (SP) Smallholders (R/T)</i>	1,000	1,500	1,500	1,500	2,000
<i>SP Irrigation board (R/T)</i>	1,200	1,500	1,500	1,500	2,000
<i>SP Industry (R/T)</i>	100	100	80	80	100
<i>SP Mine (R/T)</i>	13,500,000	13,500,000	11,000,000	11,000,000	15,000,000

Table 1 – Exogenous factors modified during the game session

Players	Performance criteria
Smallholder 2	12.41
Smallholder 1	12.24
IB 2	9.15
Mine	7.12
Industry	6.07
IB 1	5.41
CMA	6.06
CMA (off-stream)	6.82
CMA (in-stream)	4.23

Table 2 – Performance criteria and players ranking at year 5 of the game session

ANNEX: Determination of the players' performance criteria (PC)

For the economic agent i , annual profits (matured at the end of each year) are cumulated at the end of the played period. The following formula allows this calculation:

$$P_{ni} = \sum_{t=0}^n p_{ti} (1+r)^{n-t}$$

Where:

P_{ni} = cumulated profit of player i at year n

p_{ti} = annual profit of player i at year t (NB: it starts at year 0 = initial state)

r = interest rate

The performance criterion for the economic agent i over the period n (PC_{ni}) can be indicated as the increase of the cumulated profit divided by the initial annual profit (which corresponds to the cumulated profit at the year 0). It is given by the equation:

$$PC_{ni} = \frac{P_{ni} - P_{0i}}{P_{0i}} = \frac{\Delta P_i}{P_{0i}}$$

It has to be noted that, for the same r and over a given period, PC_{ni} is independent from the magnitude of the initial annual profit (i.e. the size or the sector of the economic agent). It just reflects the performance of the economic agent i over this period.

It is therefore a good indicator for comparing the economic performances of economic agents that have different size and water productivity.

The sum of all economic agents' profit at the end of the played period corresponds to the off-stream benefit from water at year n (OB_n):

$$OB_n = \sum_{t=0}^n \sum_{i=1}^k p_{ti} (1+r)^{n-t} \quad \Leftrightarrow \quad OB_t = \sum_{i=1}^k p_{ti}$$

OB_t excludes CMA revenues at time t .

In-stream benefits are also calculated and correspond to the sum of indirect (environmental) and direct (income coming from fishing activities) values of the Reserve.

$$IB_t = IVR_t + DVR_t \quad \Leftrightarrow \quad IB_n = \sum_{t=0}^n IB_t (1+r)^{n-t}$$

Total benefits from water at the catchment level and at year n can therefore be calculated as:

$$TB_n = IB_n + OB_n = \sum_{t=0}^n [IB_t (1+r)^{n-t} + OB_t (1+r)^{n-t}]$$

A *global economic performance in the basin* at the end of the played period (PCB_n), can finally be calculated. This results not only from the economic efficiency of the water use in the different sectors, but also from the environmental protection of the resource (indirect values) as well as from the rural communities' access to the in-stream water (equal access to the resource = social equity).

$$PCB_n = \frac{TB_n - TB_0}{TB_0}$$

PCB_n can then be compared with performance criteria that look at off-stream (productive) water and in-stream (fishing+indirect value) uses of water.

The performance indicator for in-stream water in the basin is:

$$PCIB_n = \frac{IB_n - IB_0}{IB_0}$$

The performance indicator for off-stream water in the basin is:

$$PCOB_n = \frac{OB_n - OB_0}{OB_0}$$