Accompanying Local Stakeholders in Negotiation Processes Related to Water Allocation Through Simulation Models and Role-Playing Games: an Experience from South Africa

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Abstract

South Africa is currently undertaking a process of radical reform in the water management sector. Following the National Water Law of 1998, new water institutions are being established to provide a decentralized and participatory management of the resource. These institutions, namely the Catchment Management Agencies (CMAs) and the Water User Associations (WUAs), represent public and private interests and define local water allocation strategies.

The new water management institutions have the complex task of matching different and sometimes-contradictory objectives in a socio-economic context characterized by inequalities, lack of or asymmetry of information, and conflicting interests. Hence, a clear need for negotiation and decision support tools for these institutions is perceived.

Furthermore, 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.

In this context, tools such as simulation models and role-playing games, able to represent the complexity and the uncertainty of the above-mentioned processes, seem to be particularly appropriate.

A community of researchers called ComMod (Companion Modelling) developed recently a scientific posture regarding the adoption of simulation models and role-playing games for participatory management of natural resources. The ComMod approach is being adopted to facilitate multi-stakeholder negotiations related to water allocation in a South African water catchment (the Kat River, in the Eastern Cape) where a WUA was recently established.

This paper illustrates and discusses the main steps undertaken and foreseen for the adoption of the ComMod approach in the Kat River catchment.

1. Introduction

During the last twenty years, the concept of decision-making on natural resources has been criticized and modified by various research communities within almost all disciplines. In social sciences, for instance, ecological economics (Costanza, 1989; Ramos-Martin, 2003) and neo-institutional economics (Bromley, 1982; Soderbaum, 1992) have addressed issues such as uncertainty and incomplete information that were not explicitly taken into consideration by the conventional mainstream environmental economics (Janssen and Ostrom, 2004).

Furthermore, there is a tendency for the top-down centralized decision making processes to be replaced by decentralized governance actions. In the developing

countries this transfer of responsibilities on the management of common pool resources is particularly striking and follows the general democratisation process. In response, new stakeholders and new local institutions emerge in the modified social frameworks. These entities need tools and approaches to help them in their decision-making and negotiation processes related to natural resource management.

In South Africa, the new national water legislation (1998) introduces a modern framework of integrated resource management in a social context still affected by severe gaps and backlogs inherited by the Apartheid regime that ended in 1994. While there is a political imperative to promote the democratisation of decision making regarding the use of water, local institutions do not yet have the capacity or the tools to take on board these responsibilities. This paper presents and discusses an innovative action-research approach aimed at facilitating negotiation and decision-making capacity on water management at a local scale. The Kat River catchment in the Eastern Cape of South Africa is the study area.

The paper is organised as follows: section 2 provides an overview of the recent developments in the South African water sector institutional and legal frameworks; section 3 illustrates the Kat river context of multi-stakeholder negotiation around water; section 4 introduces the Companion Modelling approach and describes the negotiation tools that are being developed in the Kat; some elements of discussion are provided in section 5.

2. Institutional and legal frameworks in the South African water sector

The new National Water Act of South Africa (NWA, 1998) promotes integrated and decentralised water resource management in a new institutional environment. Social development, economic growth, ecological integrity and equal access to water are key objectives of the new water resource management legislation. Under the new NWA, water is considered a public resource. Only the right of use - and not ownership - is granted to users, through a license system for which they are required to pay. Protective measures have been introduced to secure water for basic human needs and ecological requirements (the concept of the Reserve) and development purposes (Farolfi and Perret, 2002). Another major feature of the NWA is decentralisation of water management through catchment level water management institutions such as Catchment Management Agencies (CMAs) and Water User Associations (WUAs) These institutions are in the process of being established at the regional and local level, reflecting a more participatory approach to water resource management.

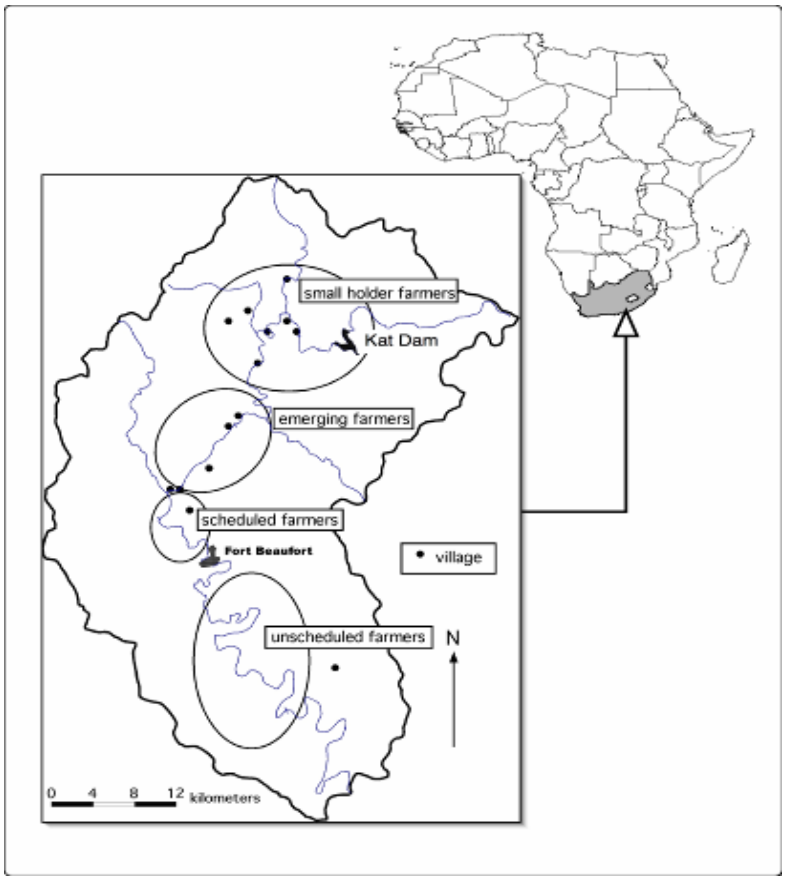
The National Water Resource Strategy (NWRS) is the implementation strategy for the NWA. It provides the legal framework for the future management of water resources in South Africa (DWAF, 2002). The main objective of the NWRS is to match and balance water demand with water supply, in accordance with the sustainability, equity and efficiency objectives of the NWA. The implementation of the Act and the NWRS raises many social questions and economic uncertainties, against a background of water scarcity, profusion of users and uses, backlogs and inequalities in infrastructure and water supply. In this context, it is believed that one of the key roles of CMAs and WUAs will be 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 institutions to accomplish their complex tasks.

3. Multi-stakeholder negotiations around water in the Kat River catchment

The Kat River valley (Map 1) is situated in the Eastern Cape province of South Africa. The river is a tributary of the Great Fish River and falls within the Fish to Tsitsikamma Water Management Area. Although the watershed has a relatively high rainfall, much of the climate of the 1,700 km^2 catchment is sub-humid to semi-arid. The area is either marginal for or unsuitable for rainfed agriculture; only through irrigation using water from the Kat River can the agricultural potential of fertile land on the valley floor be realised. To understand the nature of multi-stakeholder negotiations around water in this catchment it is necessary first to take a brief look at the history of land use and access to water among different groups. Various authors have described the historical geography of the Kat Valley (Motteux, 2001, 2003; McMaster, 2002; Fox, 2005). This account is taken from these various sources as well as from personal observations of the second author.



Map 1 – The Kat River Catchment (Rowntree, 2005)

The present land use in the catchment is the result of a complex history of politically driven changes to land access since the time of settlement by white colonialists in the early nineteenth century. Until the 1970s much of the land in the catchment was under white ownership, irrigators relied on the natural flow in the river. In 1969 the Kat Dam having a 24 Mm^3 storage capacity was completed.

In 1980 white farmers in the 'upper Kat' were forced off their farms (through compulsory purchase) and their land was incorporated into the self-governing state of Ciskei. Each farm became the nucleus of a small 'village'. Some of the more productive citrus farms were taken over by a Ciskei parastatal, Ulimocor, under the management of black farmers. In the 'middle' and 'lower' Kat the land remained as part of the Republic of South Africa, under white ownership. Irrigated citrus farms continued to be productive.

In 1994 far reaching political changes took place in South Africa with the change to a black controlled government and the reincorporation of the self governing states such as the Ciskei into the republic. From 1994 groups of ex farm labourers began to revitalise the irrigated lands in the upper catchment to form smallholder cooperatives to growing a variety of vegetables. These smallholders do not hold water licences.

Many of the state run Ulimocor citrus farms further down the valley had by 1994 become unproductive, but a few had been better managed. These farms were scheduled for irrigation and were licensed for water use.

In the 'middle' and 'lower' Kat white land owners had continued to run commercial citrus farms, mostly for the new export markets, that relied on irrigation using water from the Kat River.

While all farms in the middle and lower Kat rely on the Kat River for irrigation water, two systems of access to water are in place. The first is that of scheduled use. Annual licence fees are paid according to the area of a farm that has been scheduled for irrigation. All farms in the middle Kat, above the town of Fort Beaufort, are part of the scheduled area. Below Fort Beaufort, the lower Kat farmers opted out of the scheduled scheme and therefore do not pay an annual licence. They rely on storing the excess water flowing past the upstream farmers in large instream weirs.

We can see from the above overview that there are four groups of irrigators in the Kat Valley: small scale black farmers, often forming cooperatives, large scale 'emerging' black farmers, white commercial farmers with scheduled water rights, white commercial farmers without scheduled water rights. There is close to 19 km^2 of irrigated land or just over 1% of the catchment area. Of this, 11.5 km^2 is currently under citrus (Farolfi and Jacobs, 2005), using between 0.6 and 0.75 Mm^3 of water per square kilometre per year (Edgren, 2005). Although the catchment is not at present water stressed, there are historical inequalities between water use and access to water that will drive any future negotiations. There is desire among all user groups to expand their water use, and potential new user groups such as tourism that could impact on water issues.

While irrigation takes up by far the majority of water in the catchment, domestic water users (about 49,500 habitants in 2001) are an important stakeholder group. In the upper Kat most households get their water directly from the river and make use of pit latrines. Domestic water users whose water needs are not supplied by a municipality are classed as Schedule 1 water users under the National Water Act.

Schedule 1 users have the right to take water directly from a water resource for reasonable domestic use, home gardens and livestock watering. Their immediate concern is for a regular supply of good quality water. In the long term most domestic users would prefer to have water supplied to the home, but payment may be an issue.

The Nkonkombe Municipality is a bulk water user, supplying water to the town of Fort Beaufort and surrounding rural area. The only settlements with a water-borne sewerage system are the towns of Seymour and Fort Beaufort. A few villages have the advantage of piped water at least in the form of street taps, but quality of piped water is an issue if it comes from a groundwater source. There is a catchment wide demand for improved domestic water supply and sanitation facilities that must be addressed by the municipality or water service provider.

These then are the main water related stakeholders in the Kat Valley: the four groups of irrigators, domestic water users and the Municipality. The complex and contentious political history of the valley has given rise to a power dynamic that historically has favoured the white commercial farmers at the expense of the black population. These white farmers controlled water use through the Kat River Irrigation Board. As part of the redress process, all irrigation boards have been required under the National Water Act to transform themselves into Water User Associations (WUA) that are representative of all water users in the area.

The Kat River WUA came into being in December 2001 when its constitution was gazetted by the Minister of Water Affairs and Forestry. The process had begun in October 1999 when the commercial citrus farmers from the Kat River Irrigation Board approached researchers from Rhodes University for assistance in facilitating the transformation to a broader WUA that represented all water users in the Kat Valley. Water users represented on the WUA are at present as follows: large scale irrigators (over 5ha), small scale irrigators (under 5 ha), domestic users (Schedule1 users) and the municipality. In addition there are representatives from the Kat River Catchment Forum, a body that came about as a result of action research and capacity building carried out by researchers from Rhodes University. The Catchment Forum is a group representing mostly Schedule 1 users who are concerned about catchment management and water use issues in the ‘upper’ Kat. The constitution of the WUA includes the following objectives: to provide water for the beneficial use of members; to actively care for and manage the health of the Kat River and Kat Dam through educational programmes. Under ancillary functions the WUA is mandated to “provide catchment management services to or on behalf of responsible authorities”.

4. Action research and stakeholders’ involvement through the development of simulation models and role-playing games

Capacity building research has been ongoing in the Kat Valley since 1997 when a masters student from Rhodes (Ms Nicole Motteux) began the research that lead to the formation of both the WUA and Catchment Forum. Her research (Motteux, 2001; 2003), as did that of others after her (McMaster, 2002), focussed on the use of participatory approaches to water resource management. The institutional outcomes and stakeholder capacity developed from this previous work provided the platform for the facilitation of stakeholder-driven catchment management plan that formed the basis of a Water Research Commission (WRC) funded project: “A Stakeholder

Driven Process to Develop a Catchment Management Plan for the Kat River Valley" that began in 2004. The viability of the WUA as an effective agent of change in the Kat Valley was limited by delays foreseen in regional DWAF being able to determine the Reserve and develop a water allocation plan. The current WRC research project supports a process through which the WUA will undertake to develop its own negotiated Catchment Management Plan, including water allocations. This project provides the context within which the Companion Modelling approach described below is being implemented.

Simulation models (SM) and role-playing games (RPG) are increasingly adopted for educational purposes as well as for dealing with negotiation issues (Barreteau, 2003; Meadows and Meadows, 1993; Farolfi *et al*., 2004). A SM and a RPG are being developed to contribute to the process of building the capacity of groups of stakeholders in the Kat River catchment to understand and design their own negotiation process and to select decision-making criteria for their catchment.

The development of the model AWARE (Action research and Watershed Analysis for Resource and Economic sustainability)[1] in the Kat River catchment follows a scientific posture called Companion Modelling (ComMod). According to this approach, "Stakeholders learn collectively by creating, modifying, and observing simulations. When carrying out simulations, one acts on the decision-making process by creating or modifying representations. ComMod leads stakeholders to share representations and simulations taking into account possible decisions and actions (management rules, new infrastructures, etc.) that are under consideration within their own environment. Simulation accompanies an iterative research process that is specific to each situation. The endless following cycle *field work-> modelling -> simulation -> field work again, etc.* corresponds to this concept. This leads to a diversity of models and methods, each contributing to a new kind of relationship between the simulation, the research itinerary, and the decision-making process" (The ComMod research team, 2004).

In the case of the Kat River catchment, the Companion Modelling process is implemented by co-developing the model AWARE with the local WUA. This model is currently at a prototype stage (first version). Playing a role-playing game derived from the model will facilitate its comprehension by stakeholders and lay the basis for further discussion and model development. The cycle that is being adopted in the Kat River is illustrated in Figure 1.

[1] This paper focuses on the Companion Modelling process and not on the description of the model. Only a quick overview of the AWARE prototype that is being developed in the Kat is provided at the end of this section. A detailed description of previous versions of AWARE developed in other catchments can be found in Farolfi-Hassan (2003) and in Hassan-Farolfi (2005).

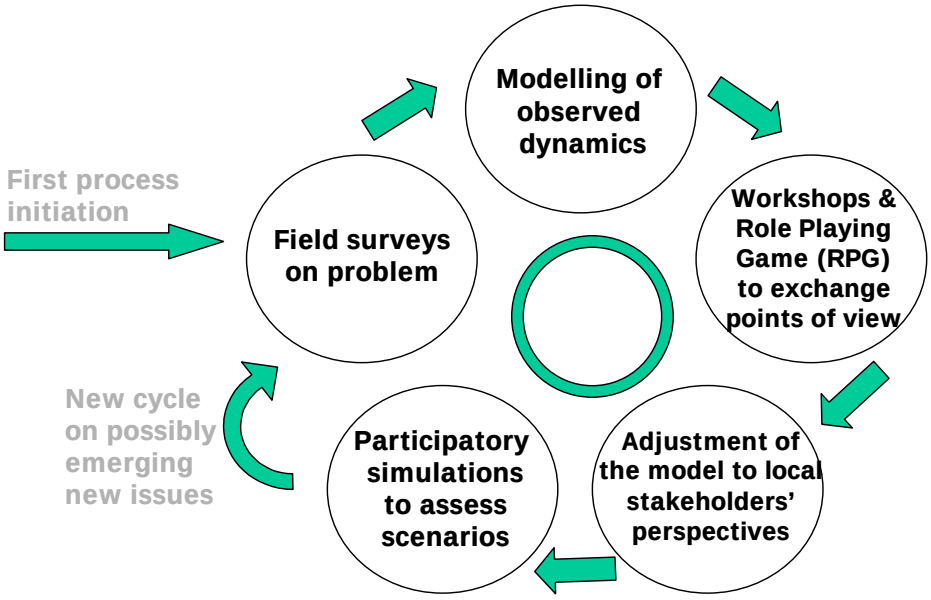


Figure 1 – The Companion Modelling approach (adapted from Cirad, 2005)

A first workshop, in which the majority of representatives of the Kat River Water User Association participated, took place in June 2005. Representatives came from a wide range of socio-economic groups that included large-scale farmers, small-scale farmers, domestic users and the local municipality. During this workshop, local stakeholders discussed and approved the ComMod process and the prototype of the AWARE model. Before presenting the model itself, working group sessions allowed the strategies and concerns of each group of stakeholders to be presented and discussed. Figure 2 shows participants using wooden blocks to build histograms representing their seasonal water use. This helped them to understand the computer generated graphs shown later as part of the model output. Moreover, these representations of water used were incorporated in to the next version of the model that was used in the second workshop.

A second workshop scheduled in September 2005 is aimed at discussing the modified version of the model so that it can be developed further to better represent the Kat situation. The model will also be presented as a negotiation tool for use by the WUA representatives.

In November 2005 a role-playing game session will be run in which the stakeholders take the place of the model's agents and act according to their own strategies over an eight-year period. The game outcomes are calculated by the same model as previously described. Through playing this game the actors get a better understanding of its functions. This session will also provide further information regarding local water users' strategies and behaviors to be introduced in a third version of the model. This new version will be presented and discussed in 2006.

This participatory process of "learning by doing" (Liu, 1996) or "social learning" (Röling, 1994; Allen, 2000) that results from companion modelling sessions refers to

current trends in social sciences, with particular reference to action research (Dick and Dalmau, 1999; Allen, 2000). During the development of the model, the "doing" phase consists of verifying the rules and practices of the implementation of the water management business plan, as well as the parameters introduced by researchers and discussions of the scenarios run. The "learning" phase emerges from the discussions among stakeholders and with the research team, and the consequent push to re-consider the potential consequences of the adoption of water allocation strategies on socio-economic and environmental indicators.

Figure 2 – Groups discussing water demand over an year during the first Companion Modelling workshop with the Kat River Water User Association (picture by B. Bonté)

The use of repeated cycles of modelling and discussion sessions enables action researchers and their partners to reach progressively more appropriate conclusions (Figure 3). It is equivalent to what some authors call the "hermeneutic spiral" (Gummesson, 1991).

Another important issue addressed by following a Companion Modelling approach to build-up social knowledge about decentralized water management is the uncertainty that results from complex systems' dynamics. Uncertainty leads to top-down oriented decision-support tools being considered less useful than negotiation-support and discussion-facilitating tools such as SM and 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 for putting in place processes of discussion, empowering and negotiation among stakeholders in order to facilitate governance (Ostrom, 1990) and participatory bottom-up management processes.

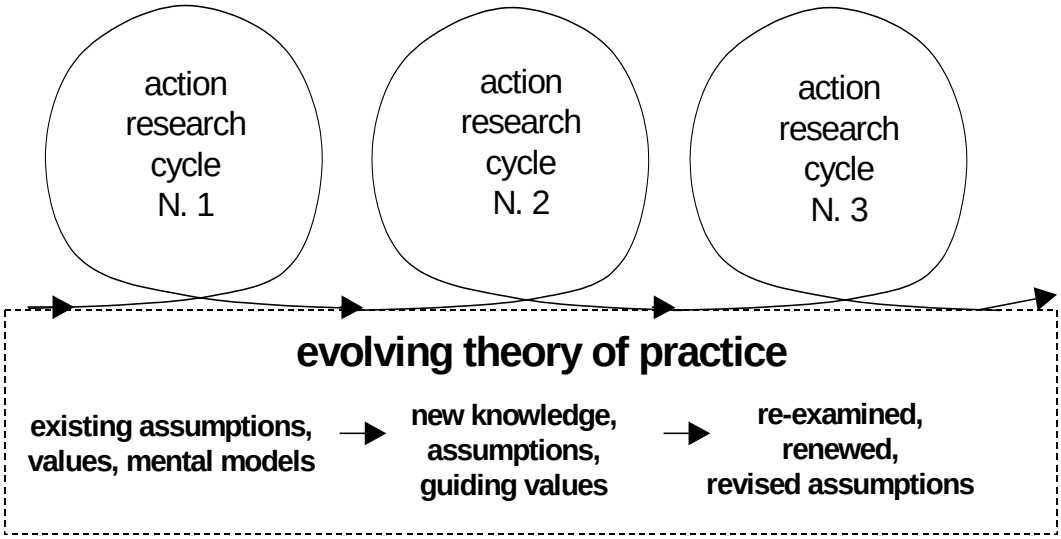


Figure 3 – The iterative nature of action research (Allen, 2000)

The model AWARE looks at the impacts on socio-economic and environmental indicators of different water management strategies adoptable in a catchment. It is an attempt to analyse water policy implementation at the local level and from an integrated viewpoint.

The version of AWARE currently developed in the Kat River catchment is a multi-agent system (MAS) based on a modelling platform called Cormas (Bousquet *et al*. 1998). The choice of MAS to implement the new version of AWARE is due to the fact that MAS are simulation tools tailored specifically for studying interaction dynamics. As a consequence, they provide a perfect basis for modelling social and ecological dynamics such as water use and allocation by multi-stakeholders. The model simulates different scenarios of water allocation strategies among groups of stakeholders in the Kat and their consequences over a period of ten years in terms of water demand, income and profit generation, job creation, etc. AWARE allows us to show each dynamic on a map representing the catchment (Figure 4). This proved crucial to facilitate local stakeholders' comprehension of ecological, social and economic consequences of the adoption of alternative water allocation strategies.

Three scenarios were simulated and discussed with the Kat River WUA during the above mentioned first workshop: 1) Smallholders in the Upper Kat move progressively into citrus production; 2) Citrus surface increases by 70% over 10 years; 3) Domestic water supply improves progressively.

The working groups held during the first workshop allowed all stakeholders to express their concerns and strategies about water use and availability over the next ten years. Reports from each group provide the elements to refine the scenarios and assumptions introduced in the second version of the model. For instance stakeholders in the lower Kat pointed to the need to model in-channel storage behind weirs. Rules were changed relating to the manner in which releases from the dam were assumed to be operated.

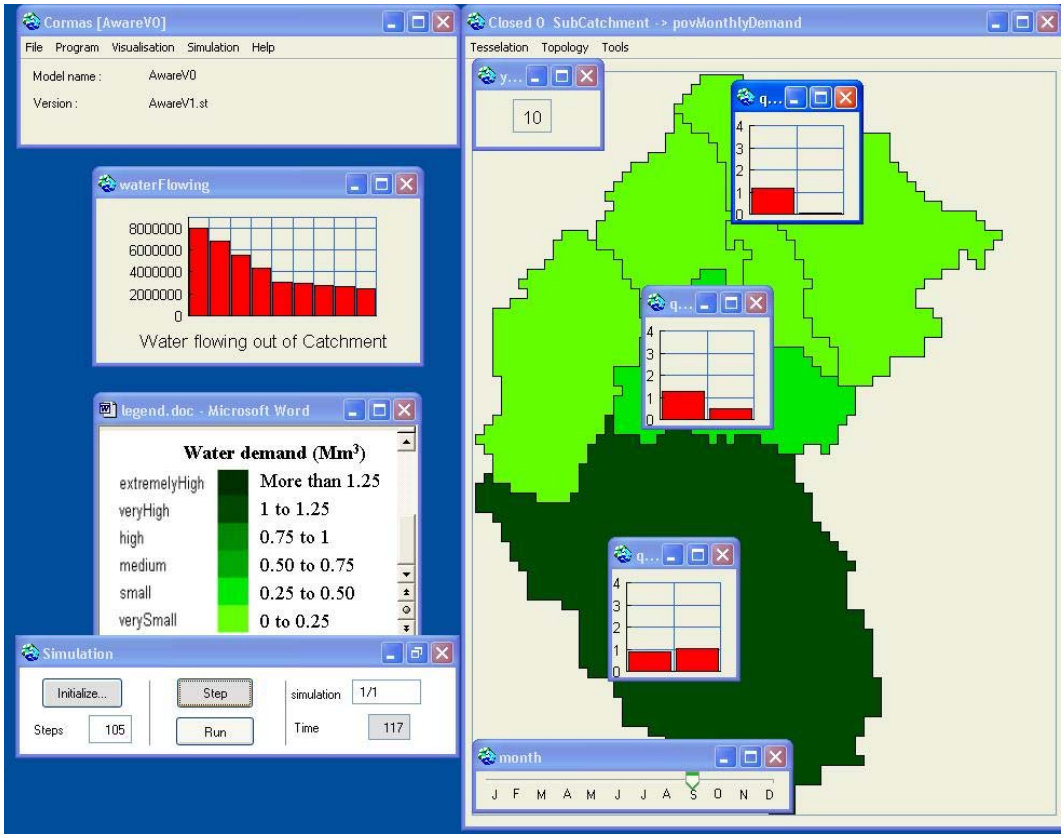


Figure 4 – A simulation interface in AWARE

The presented visualisation (Figure 4) comes from a simulation showing the dynamics of water demand in different sub-catchments of the Kat River over ten years if a specific strategy of water allocation is adopted (here scenario 2: Citrus surface increases by 70% over 10 years). Every simulated month (time step) the colours of the map change according to the indicated legend. Two windows show simultaneously the year and the month of each time step facilitating the follow-up of the dynamics. The three groups of histograms on the map show for every month the relation between water availability (left) and water demand (right) (in million m^3) in three representative sub-catchments. The amount of water flowing annually out of the catchment is indicated in the window beside the map, where a histogram is added at the end of each simulated year. Figure 4 shows the state of the catchment at year 10, month of September.

To help discussion of the outcomes of different water allocation strategies over the ten simulated years, graphs summarizing the results from each scenario are produced by AWARE on socio-economic indicators such as income generation and job creation per sector or for the whole catchment.

5. Discussion

This paper presented an on-going application of an innovative approach called Companion Modelling (ComMod) to facilitate multi-stakeholder negotiations around water allocation in the Kat River Catchment of South Africa. As the process is ongoing, only some elements of discussion may be proposed at this stage.

Developing AWARE SM and playing the derived RPG in a context of a real negotiation process for the use of a limited water resource has the main advantage of providing a common framework of knowledge and information regarding the processes relating to water allocation to all the stakeholders (here their representatives) of a specific watershed.

During the workshops, focus is not only on the results and the figures that are obtained (scenarios), but rather on the dynamic processes and interactions 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 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 process contributes to raising questions, stimulate discussions, and fosters an exchange of ideas and knowledge that reduces this asymmetry of information.

Accordingly, the ComMod approach follows the post-normal science posture, for which the final objective is not decision-making and production of definitive results, but rather to enrich the process of multi-stakeholder negotiation contributing to participatory decision-making. In other words, the ultimate measure of success is not the quality of the choices, but rather the quality of the process that leads to these choices.

Acknowledgments

This paper illustrates an approach being applied within the project "A Stakeholder Driven Process to Develop a Catchment Management Plan for the Kat River Valley" funded by the Water Research Commission of South Africa.
The authors gratefully thank the "Social team" at Rhodes University,lead by Jae Burt, the Kat River Water User Association and the Kat Catchment Forum. Their contribution is instrumental to the implementation of the described process.

References

ALLEN, W (2000), The role of action research in environmental management, working paper on the website : http://nrm.massey.ac.nz/changelinks/ar_working.html

BARRETEAU, O (2003), The joint use of role-playing games and models regarding negotiation processes: characterization of associations. Journal of Artificial Societies and Social Simulation, vol. 6, n. 2, http://jasss.soc.surrey.ac.uk/6/2/3.html

BOUSQUET, F, BAKAM, I, PROTON, H and LE PAGE, C (1998), Cormas: common-pool resources and multi-agent Systems. Lecture Notes. Artificial Intelligence,1416, 826-838.

BROMLEY, DW (1982), Land and water problems : an institutional perspective, American Journal of Agricultural Economics, 64 (5), 834-844.

CIRAD (2005), Collective learning with modelling to enhance adaptive management of socio-ecological systems. Cirad Leaflet.

COMMOD RESEARCH TEAM (2004), ComMod : a Companion Modelling Approach, web site: http://cormas.cirad.fr/en/reseaux/ComMod/charte.htm

COSTANZA, R (1989), What is ecological economics?, Ecological Economics, vol. 1, Issue 1, 1-7.

DICK, B and DALMAU, T (1999), Values in action: applying the ideas of Argyris and Schön, second edition. Brisbane, Qld: Interchange.

DWAF (2002), National Water Resource Strategy (Proposed 1st ed.) Summary. August. 37p.

EDGREN, J (2005), Water the most critical factor in citrus production?, Unpublished Honours' report, Rhodes University , 41 p.

FAROLFI, S and HASSAN, RM (2003), AWARE: a decision support tool towards decentralised water management in South Africa. Proceedings. Int. Conf. Water Governance and Sustainable Development. Sousse (Tunisia). 9-10 October.

FAROLFI, S, HASSAN, R, PERRET, S, and MACKAY, H (2004), A role-playing game to support multi-stakeholder negotiations related to water allocation in South Africa: first applications and potential developments , Proceedings of the Conference : Water Resources as Ecosystems: Scientists, Government and Society at the Crossroads, Midrand, 5-7 July.

FAROLFI, S and JACOBS, J (2005), Water availability, requirements, and water-related socio economic aspects of the Kat River catchment: a survey on secondary data, unpublished report, WRC Project no. K5/1496, 34 p.

FAROLFI, S and PERRET, S (2002), Inter-sectoral competition for water allocation in rural South Africa: Analysing a case study through a standard environmental economics approach. Proceedings. XXXIX Symp. of the Italian Society of Agricultural Economics (SIDEA). Florence. 12-14 September.

FOX, HE (2005), The role of anthropogenic disturbance in the creation of a socio-ecological landscape. Unpublished MSc thesis, Rhodes University, South Africa.

FUNTOWICZ, SO, MARTINEZ-ALIER, J, MUNDA, G and RAVETZ, JR (1999), Information tools for environmental policy under conditions of complexity, Environmental issues series, n. 9, EAA, 34 p.

GUMMESSON, E (1991), Qualitative methods in management research. Newbury Park: Sage.

HASSAN, R and FAROLFI, S (2005), Water value, resource rent recovery and economic welfare cost of environmental protection: a water-sector model for the Steelpoort sub-basin in South Africa, Water SA, Vol 31, n. 1, 9-16.

JANSSEN, M and OSTROM, E (2004), Governing social-ecological systems, in: Judd KL and Tesfatsion L (Eds.) Handbook of computational economics II: Agent-based computational economics.

LIU, M (1996), Action research and development dynamics, in: Sebillotte (ed.) System-oriented research in agriculture and rural development, Proceedings of the international Symposium held in Montpellier (F), 21-25 november 1994, Cirad, 111-116.

MCMASTER, A (2002), GIS in participatory catchment management : a case study in the Kat River Valley, Eastern Cape, South Africa, Unpublished MSc thesis, Rhodes University, South Africa.

MEADOWS, D and MEADOWS, D (1993), Fish Banks news. Durham, NH, USA: Fish Banks limited and Laboratory for Interactive Learning of New Hampshire.

MOTTEUX, N (2001), The development and co-ordination of catchment fora through the empowerment of rural communities. Water Research Commission Report Number: 1014/1/01

MOTTEUX, N (2003) Evaluating people-environment relationships: developing appropriate research methodologies for sustainable management and rehabilitation of riverine areas by communities in the Kat River Valley, Eastern Cape Province, South Africa. Unpublished PhD Thesis, Rhodes University, South Africa

OSTROM, E (1990), Governing the commons, Cambridge university press, 280 p.

RAMOS-MARTIN, J (2003), Empiricism in ecological economics: a perspective from complex systems theory, in: Ecological Economics, 46, 387-398.

RÖLING, N (1996), Creating human platforms to manage natural resources: first results of a research program, in: Sebillotte (ed.) System-oriented research in agriculture and rural development, Cirad, October, 391-395.

SODERBAUM, P (1992), Neoclassical and institutional approaches to development and the environment, Ecological Economics, 5, 127-144.