The French Agricultural Research Centre for International Development

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DEVELOPING A MULTI-AGENT MODEL IN THE KAT RIVER VALLEY: KATAWARE. REFLEXIONS ON THE PROCESS

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A STAKEHOLDER DRIVEN PROCESS TO DEVELOP A CATCHMENT MANAGEMENT PLAN FOR THE KAT RIVER VALLEY

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A USER'S GUIDE FOR THE KATAWARE MULTI-AGENT MODEL

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Terminology and Acronyms

CMP	Catchment Management Plan
ComMod	Companion Modeling
DWAF	Department of Water Affairs and Forestry
IS	Insurance of Supply
KatAWARE	The Multi-Agent model developed in the Kat River Catchment
RPG	Role-Playing Game
WRC	Water Research Commission
WUA	Water User Association

PREFACE

Within the Water Research Commission (WRC) project: “A stakeholder driven process to develop a catchment management plan for the Kat River Valley”, the Companion Modeling (ComMod) approach (Barreteau et al, 2003) was adopted to help the local Water Users Association (WUA) in the task of defining a Catchment Management Plan (CMP) for the Kat River Valley.

Two platforms, a multi-agent model named KatAWARE (Farolfi and Bonté, 2005; 2006) and a Role-Playing Game (Farolfi, 2006), were constructed in conjunction with local stakeholders through the ComMod approach.

This document reports on the use of the multi-agent model. . The following chapters refer to the Kat River ComMod experience; nevertheless some lessons learned during the described case study could be generalized to other possible applications in South Africa or elsewhere.

This report is organized as follows: Chapter one recaps quickly the main characteristics of the KatAWARE multi-agent model in its various versions; Chapter two illustrates the use of the tool during a participatory workshop with the WUA, whilst chapter three concludes and provides recommendations. In the appendix some technical information is provided, on how to install and operate KatAWARE.

1. THE THREE VERSIONS OF THE KATAWARE MODEL

The KatAWARE *prototype* model (Farolfi-Bonté, 2005) was developed on the basis of secondary and primary quantitative data, and individual surveys, interviews with local stakeholders, and inputs from the "social team" at working on the larger WRC project. The prototype was presented and discussed during a workshop held in Fort Beaufort in June 2005 (Burt et al, 2005a); during which the stakeholders were involved in verifying the manner in which water management, water uses and allocations in the Kat River Valley were represented by the model; several doubts and criticisms on specific issues were raised during this workshop.

From the discussions that took place during and around the June 2005 meeting, a new version (*V1*) of the KatAWARE model was developed (Farolfi-Bonté, 2006) and presented to the stakeholders in a subsequent workshop in September 2005 (Burt et al., 2005b). This model was more accurate in terms: of hydrology; spatial distribution of water users and their characteristics; and management of the Kat River dam and private water stock facilities'. Stakeholders found V1 a useful tool for building up scenarios of water allocation over 10 years and began discussing them in connection with the dvelopment of the WUA's the "business plan".

While the model development progressed, an associated *Role-Playing Game (RPG)* was constructed (Farolfi, 2006). The RPG was based on the same conceptual model backing KatAWARE V1, but in order to make it playable, the reality was "reduced" to three sub-catchments (Figure 1), roughly corresponding to the three voting areas of the Kat River Valley (Upper, Middle and Lower Kat). The RPG was designed to be played by 8 people, the average number of participating WUA members. The RPG playfield was composed of: three sub-catchments each one with different rainfall, two smallholding irrigation schemes (in the Upper Kat), three large-scale citrus farms (two in the Middle Kat and one in the Lower Kat), three villages (one in each sub-catchment) and a dam in the Upper Kat. The initial conditions of the RPG correspond to those of the 'real Kat' multiplied by a factor ranging between 1/3.2 and 1/13 (table 1).

The game was played for the first time in November 2005, and a second time, with some changes in parameters and set-up, in March 2006.

The main objectives of the game were: a) to aid in the generation of understanding, by the local stakeholders, about the role and functions of the KatAWARE model, from which the RPG had been designed; and b) to provide researchers with further information regarding stakeholder – both individual and collective – strategies for water use and water management in the basin.

The reports on the two RPG sessions (Fox, 2005 and 2006) indicated that stakeholders understood the exercise and actively participated in it. Player observation during the two RPG sessions provided information about the various practices and strategies players adopted; this information enabled researchers to improve KatAWARE V1, particularly in terms of agents' behaviour. A new version of KatAWARE (*V2*) was therefore envisaged.

	The model (98% insurance of supply)	**The game**	**Conv. Factor**
Dam stockage	24,000,000	4,000,000	6.0
Natural run off	13,500,000	1,800,000	7.5
Domestic consumption	1,500,000	214,200	7.0
Irrigation consumption	11,000,000	1,064,000	10.3
Surface Cabbage	180	40	4.5
Surface Citrus	1,300	100	13.0
Hab. Catchment	49,000	10,000	4.9
Annual flow out	1,600,000	500,000	3.2

Table 1 Initial parameter in KatAWARE V1 and the associated RPG (session2)

A follow-up discussion with the research team revolved around the characteristics that the V2 model should have. In particular, it was re-iterated that this is a tool designed to support negotiation and not decision; even if common decision-making is a consequence of the negotiation process that is taking place within the ComMod process in the Kat. Consequently, given the very positive response of local stakeholders with respect to the

RPG sessions (Fox, 2005 and 2006) and the high value assigned to the RPG as a tool that facilitates discussions and negotiation processes, the idea was raised of restructuring the outcomes and scenarios in KatAWARE V2 on the basis of the RPG outcomes.

This choice results in two main advantages: 1) scenarios will be based around the same sub-catchments as seen during the RPG sessions, of which most members of the WUA took part. This familiarity will increase their comprehension of the outcomes and scenarios associated with the model; 2) Instead of presenting scenarios based on relatively realistic maps and precise representation of nearly all agents in the catchment, V2 would be based on the aggregated and simplified playfield of the RPG. This should reduce the risk of interpreting KatAWARE V2 as a decision support tool and will remind everybody that this is just a tool for accompanying negotiation and preparing the discussions for common decision making.

This choice would imply that to use KatAWARE V2 the same conceptual model of V1 would be used, and proceed to the following operations: 1) aggregation and 2) multiplication by a conversion factor (1/1 to 1/13 -cf. table 0-: if 1/1 the outcomes will be comparable to those of V1, if the factors indicated in Tab. 0 are adopted, the observable outcomes will be comparable to those from the RPG sessions). In addition to this, new methods to represent individual (players) and collective (WUA) strategies will be introduced in the V2 model.

The evolution from KatAWARE V1 to V2 can be schematized as follows:

V1 **V2**

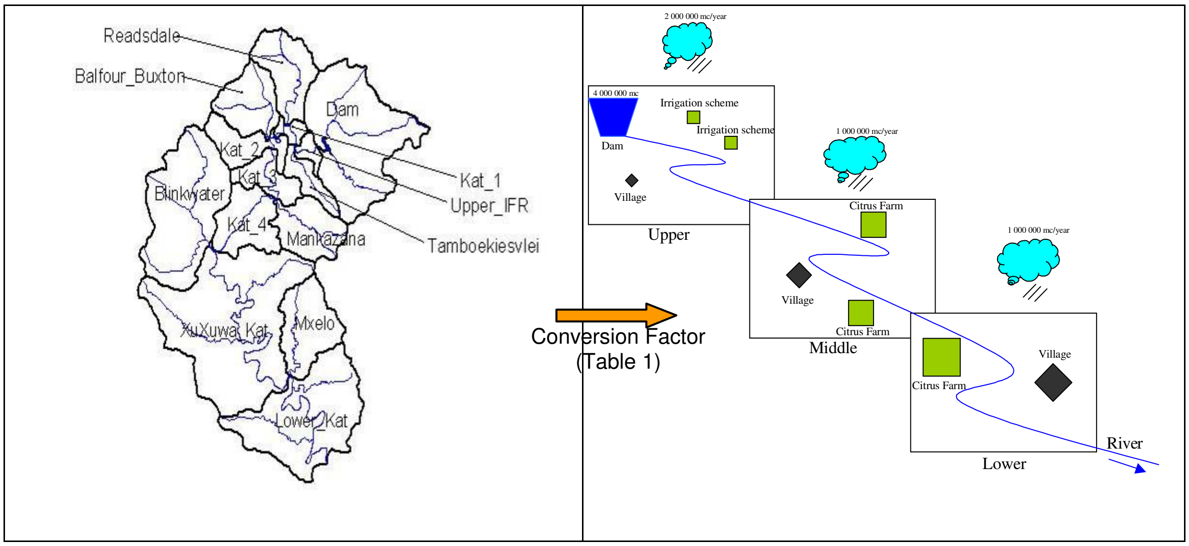

Figure 1 **From the Kat River Valley map in V1 to the simplified spatial representation in V2 (and in the RPG)**

Where Upper is an aggregation of the following sub-catchments: Dam, Tamboekiesvlei, Readsdale, Upper IFR and Kat 1; Middle is an aggregation of the following sub-catchments: Blinkwater, Kat 2, Kat 3, Kat 4, Mankazana, Balfour, Buxton; Lower is an aggregation of the following sub-catchments: XuXuwa, Kat, Mxelo, Lower Kat.

Water supply and water users in V2 result from the aggregation of figures referring to these entities in V1 and fit into the RPG scheme represented by V2. For instance, if in the Middle Kat there are 10 citrus farms and the sum of their surfaces is 780, they result in two citrus farms of 390 ha in V2 if the conversion factor is 1/1, whereas a conversion factor of 1/13 would bring the figures closer to the RPG ones (30 ha per farm for a total of 60).

Some adjustments occur during the conversion of agents and figures from V1 to V2 through aggregation and adoption of a conversion factor; but the final set-up of the latter will be as close as possible to the set-up of the RPG.

The hydrological dynamics and the socio-economic specifications (budgets, cycles, labour force, etc.) used in V1 remain the same in V2.

Although V2 of the KatAWARE model was conceptualized at the time of this report, technical delays due to the unavailability of the envisaged simulation platform (Mimosa) where V2 should have been developed hampered its use within the ComMod process in the Kat River. Therefore, this 'User's guide' refers to V1 of the multi-agent model, which was used for scenarios discussed and analysed during a workshop held with the WUA in October 2006.

2. THE USE OF THE KATAWARE MODEL V1 FOR SCENARIOS DISCUSSION AND ANALYSIS

This chapter reports on the use of the multi-agent model KatAWARE V1 within a workshop aimed at facilitating the Kat River WUA's discussions and negotiation around water allocation strategies to be formalised in the CMP.

The workshop took place in Fort Beaufort in October 2006. It was attended by several WUA members, a DWAF representative, a representative of the Nkonkobe Municipality, the Research Team from Rhodes University and the Cirad modellers.

After a recap of the functioning and the characteristics of the model, several scenarios of water allocation and their consequences in terms of income, employment generation, water use, dam use and ecological Reserve protection were presented and discussed. The time span for the scenarios was 10 years.

Scenario selection was based on: a) the results from the September 2006 workshop, during which the WUA members discussed possible visions for the future of the Kat River Valley; and b) the results of the 2 RPG sessions played in November 2005 and in March 2006.

The following main elements resulted from the mentioned sources:

- More or less the same development vision emerged in the 3 sub-catchments and in various groups of stakeholders
- The aims contained in each vision can be contradictory (e.g. more employment through more agriculture and a better protection of the ecological Reserve)

These points provide the basis for some key development questions:

- Is there enough water to reach these goals?
- What strategy of allocation must be adopted to reach these goals?
- Is some kind of compromise necessary?
- What is the role of the WUA?
- What is the role of negotiation and common decision-making?

According to the visions discussed in the mentioned workshop of September 2006 and the results of the two RPG sessions, the following scenarios were presented and simulated through KatAWARE:

Scenario 1:
Current water demand does not change over time; moderate water availability

- Natural water flow is 21.5M m^3/year = 'water available in the Kat 9 years out of 10'
- No change in water use over the 10 simulated years

Scenario 2:
Current water demand does not change over time; low water availability

- Natural water flow is 14.5M m^3/year = 'water available in the Kat 98 years out of 100'
- No change in water use over the 10 simulated years

Scenario 3:
Current water demand does not change over time; low water availability

- Natural water flow is 14.5M m^3/year = 'water available in the Kat 98 years out of 100'
- No change in water use

Scenario 4:

Domestic tap water for all

- Natural water flow is 21.5M m^3/year = ‘water available in the Kat 9 years out of 10’
- Indwelling taps for all inhabitants by year 10
- No change in crop surfaces

Scenario 5:

Domestic tap water for all and increase in crop surfaces

- Natural water flow is 21.5M m^3/year = ‘water available in the Kat 9 years out of 10’
- Indwelling taps for all inhabitants by year 10
- Increase in crop surfaces (for a total of 1700ha): smallholders double annual crops; citrus scheduled up to 900ha; non-scheduled up to 400 ha.

Scenario 6:

Domestic tap water for all and HIGH increase in crop surfaces

- Natural water flow is 21.5M m^3/year = ‘water available in the Kat 9 years out of 10’
- Indwelling taps for all inhabitants by year 10
- Increase in agricultural surfaces (for a total of 2600ha): smallholders double annual crops; citrus scheduled up to 1500ha; non-scheduled up to 700ha.

Scenario 7:

Domestic tap water for all and HIGH increase in crop surfaces, all citrus farmers scheduled

- As in scenario 6, but all citrus farmers scheduled
- More water is released from the dam in response to the demand of a higher n. of scheduled farmers

Scenario 8:

Domestic tap water for all and moderate increase in crop surfaces, all citrus farmers scheduled

- Natural water flow is 21.5M m^3/year = 'water available in the Kat 9 years out of 10'
- Indwelling taps for all inhabitants by year 10
- Increase in agricultural surfaces (for a total of 2000ha): smallholders double annual crops (400ha); citrus scheduled up to 1600ha.

Scenario 9:

Domestic tap water for all and moderate increase in crop surfaces, all citrus farmers scheduled, variable water availability

- Natural river flow varies between 21.5M m^3/year and 14.5M m^3/year
- Indwelling taps for all inhabitants by year 10
- Increase in agricultural surfaces (for a total of 2000ha): smallholders double annual crops (400ha); citrus scheduled up to 1600ha.

These scenarios were then discussed and positive/negative consequences were identified by WUA members following the provided guiding questions

- Where is the limit for water allocation to users? What sectors have to be prioritized?
- At what level is the ecological Reserve?
- Licences for all or not?
- Who pays for domestic infrastructures?
- Who pays for smallholders infrastructures?

During the workshop of October 2006, WUA members were first asked to choose some of the presented scenarios and discuss them. Scenario 5 was among the preferred ones. The following charts, obtained through KatAWARE, facilitated the discussions around the quantitative and spatial consequences of the adoption of scenario 5 over a 10-year period in the Kat River Valley.

In line with the visions for the Kat River Valley, that emerged during the workshop of September 2006, and with the results of the two RPG sessions, derived from KatAWARE, scenario 5 proposes a better domestic water provision coupled with a moderate increase of citrus surfaces and a doubled annual crops surface. This results in an increased profit and more employment for the catchment (Figures 4, 5 and 6); at the same time, the ecological Reserve (set at about 7.5Mm^3/year in Maintenance low flow years and 0.25Mm^3/year in drought flow years – Louw and Koekemoer, 2006) is respected[1] (Figure 3). In this scenario in fact, the Insurance of Supply (IS) for the catchment is set at 90%, which correspond to a relatively bad year (run off available at least 9 years out of 10). Scenarios could be run at 98% IS, representing well the drought flow years. It is worthwhile noticing that this scenario does not contemplate the scheduling of large-scale farmers in the Lower Kat currently non-scheduled. This choice on the one hand does not have a big impact on the water demand from the Kat River Dam (Figure 2), but on the other hand puts the unscheduled users in a condition of uncertainty with respect to water supply. This uncertainty is well represented in Figure 7, where the comparison in the amount of water contained in storage facilities owned by scheduled and non-scheduled citrus farmers indicates that the latter need to pump water more and more often from their ponds over the ten years of the simulation. During the dry season, unlike the storage facilities owned by scheduled farmers, their ponds can be empty and they do not have other sources to irrigate their citrus plants. As a consequence, non-scheduled farmers' profit (Figure 9) is less steady than the scheduled one (Figure 10). This has a negative consequence on the catchment profit generation too (Figure 4).

At the same time, the Kat River Dam water is not efficiently used (Figure 1) and there would be room for better utilization of what represents the only water supply management tool in the catchment.

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[1] Even if in the model some water uses (such as forestry and alien vegetation) do not appear and therefore must be added to the total annual water consumption. An addition of about 2Mm^3/year should be considered for every simulation.

In discussing this scenario, a consensus was reached around the following conclusions:

- There is enough water to satisfy the current needs in the catchment even at a very high IS;
- Reasonably, a certain development can be fostered in the catchment through more water use without compromising the ecological requirements;
- Unscheduled farmers could be licensed for the use of water from the dam;
- The dam should be used more efficiently managed in order to a) secure water to all users at a higher level of IS; and b) if necessary, contribute to the maintenance of the ecological Reserve.

These considerations triggered the group into the analysis of scenarios 7, 8 and 9, where all citrus farmers are scheduled. Different levels of IS and various increases in farming surfaces were explored in these scenarios in order to define some 'thresholds' in terms of development option and consequent water allocations to the various sectors.

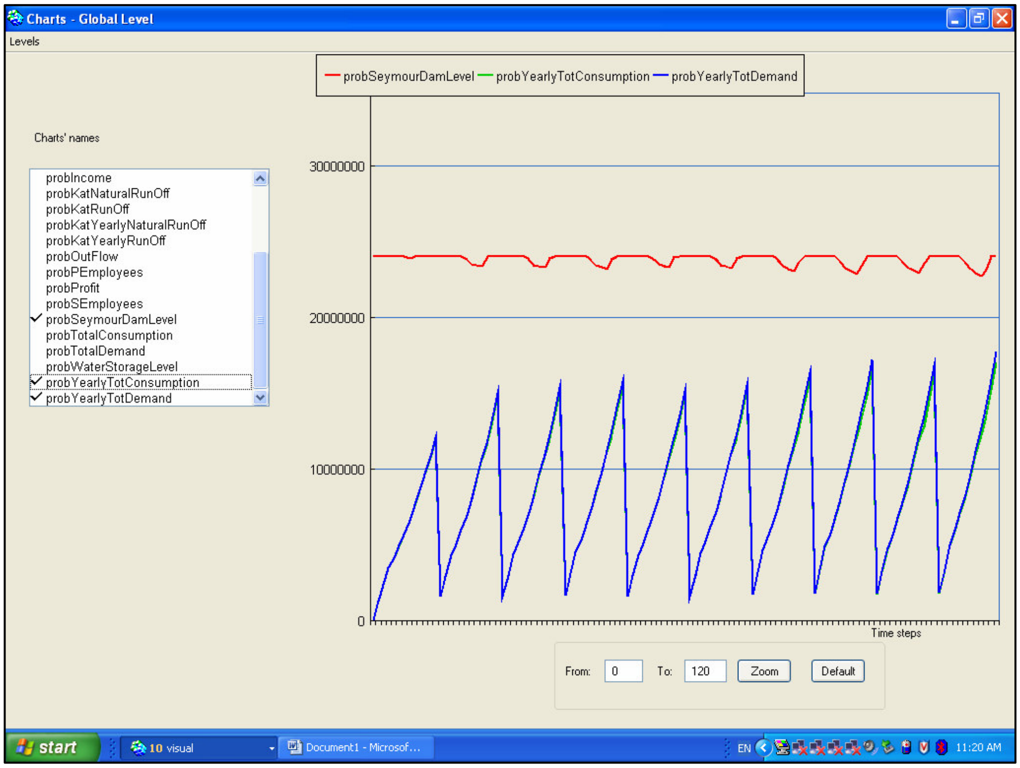

Figure 2 **Water in the Kat River Dam and yearly water demand in the Kat River Valley (000 000 m^3)**

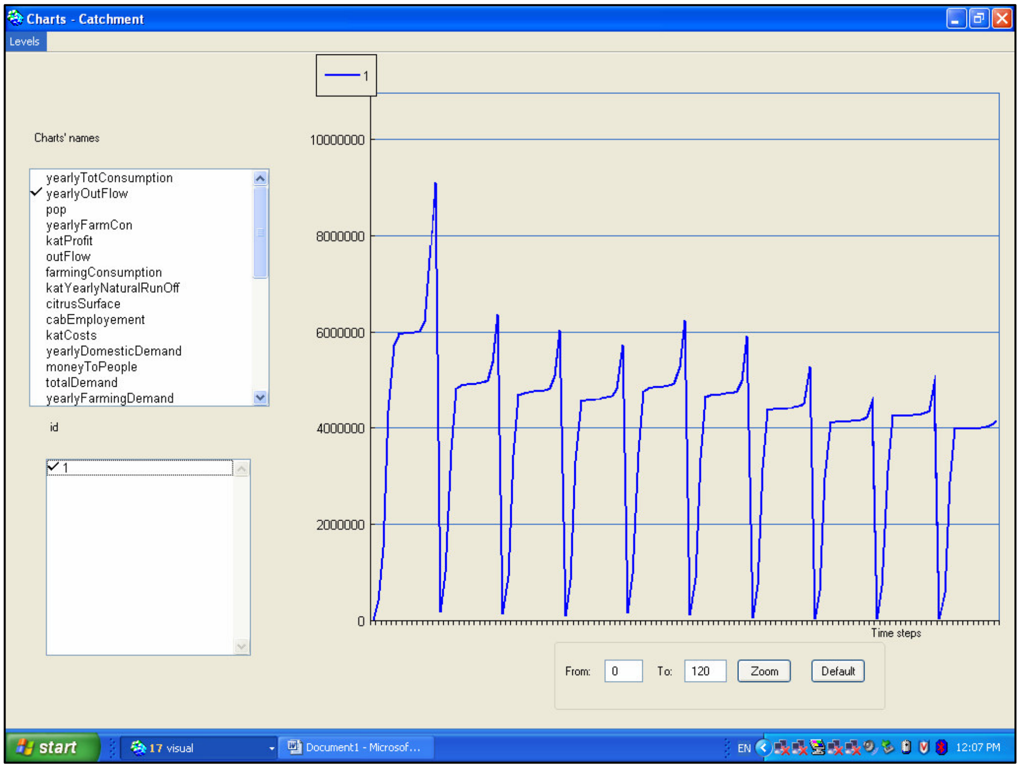

Figure 3 Water flowing out of the catchment every year (000 000m^3)

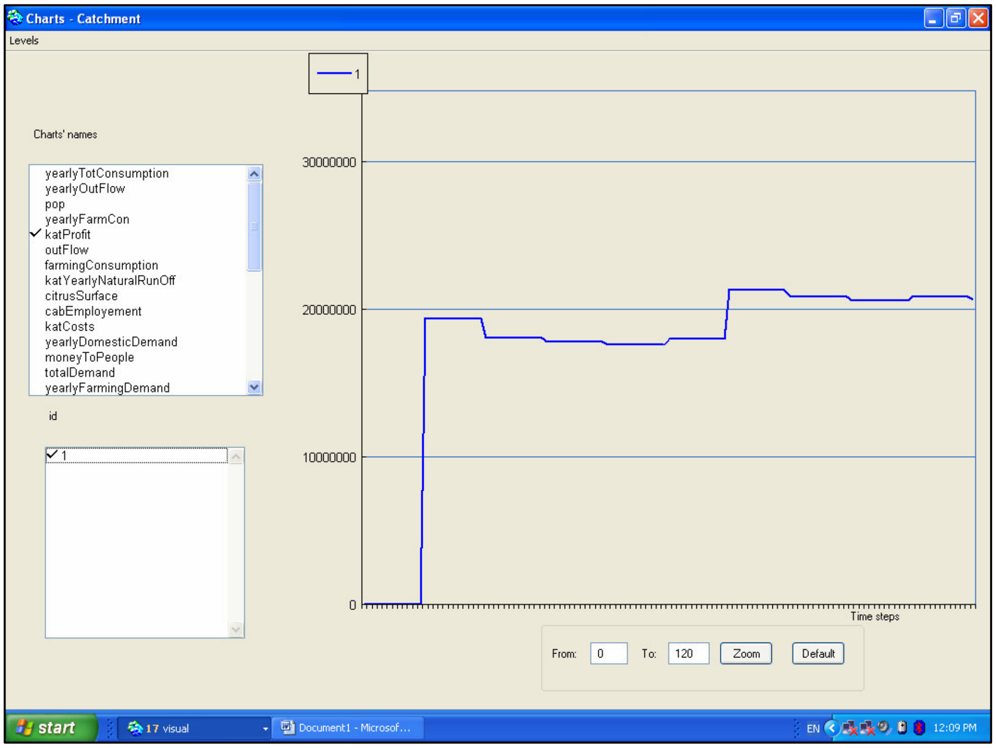

Figure 4 Total profit generated in the Catchment (ZAR)

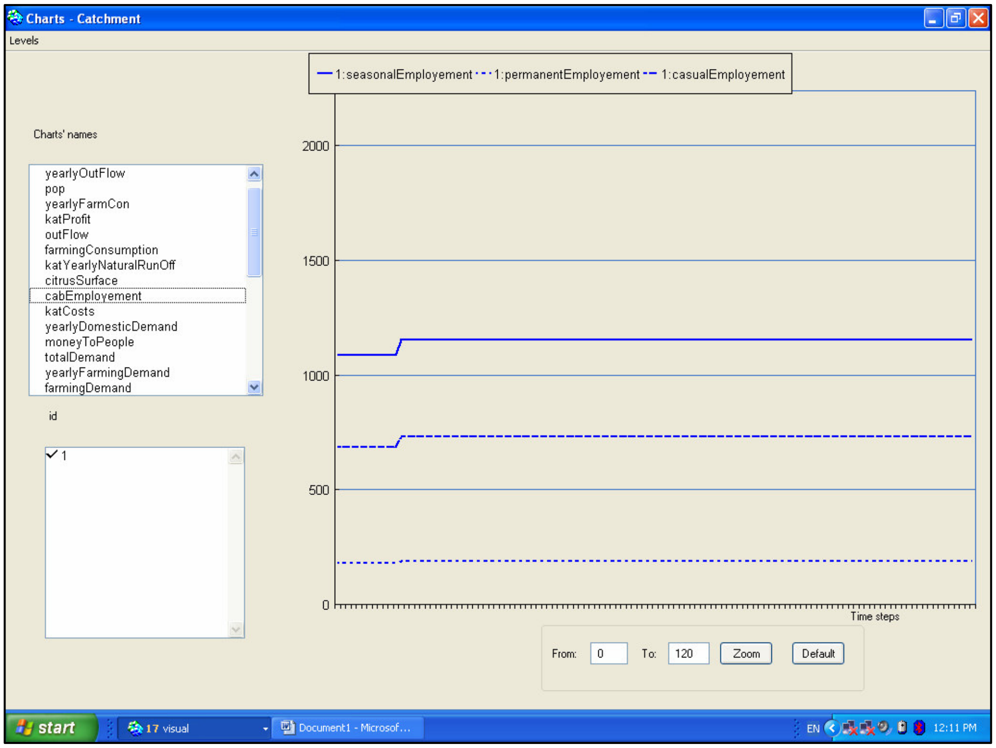

Figure 5 Permanent, seasonal and casual employment generated in the catchment (units).

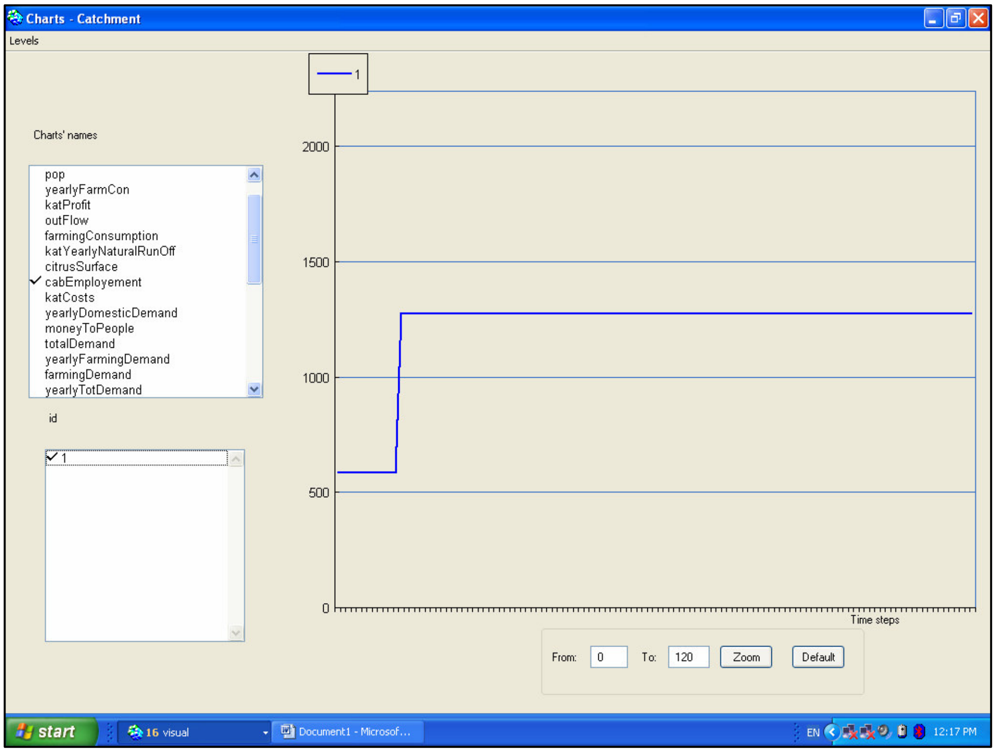

Figure 6 Casual employment generated by the smallholding sector in the catchment (units).

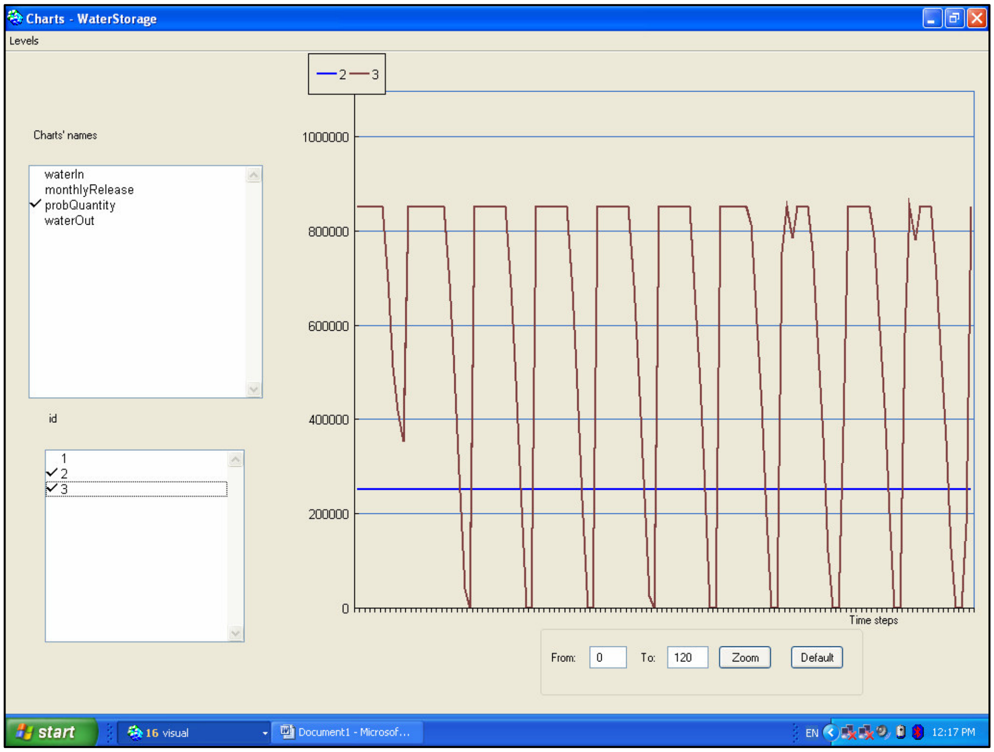

Figure 7 Water contained in the private storage facilities owned by scheduled (blue) and non-scheduled (brown) citrus farmers (m^3).

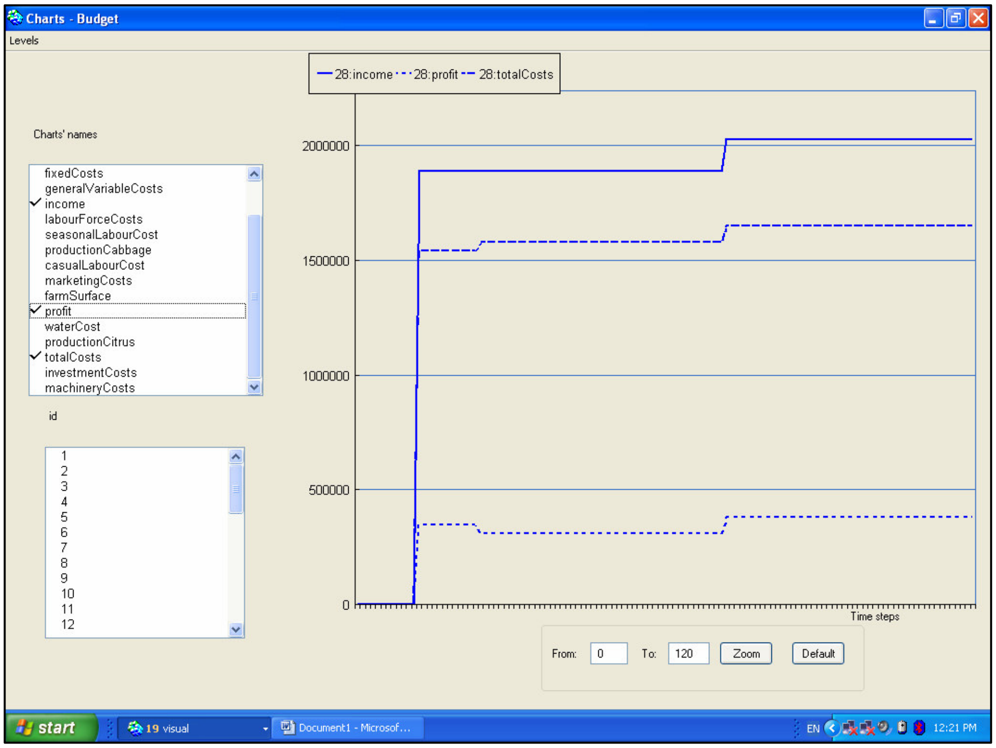

Figure 8 Annual income, costs and profit of a scheduled citrus farmer (ZAR).

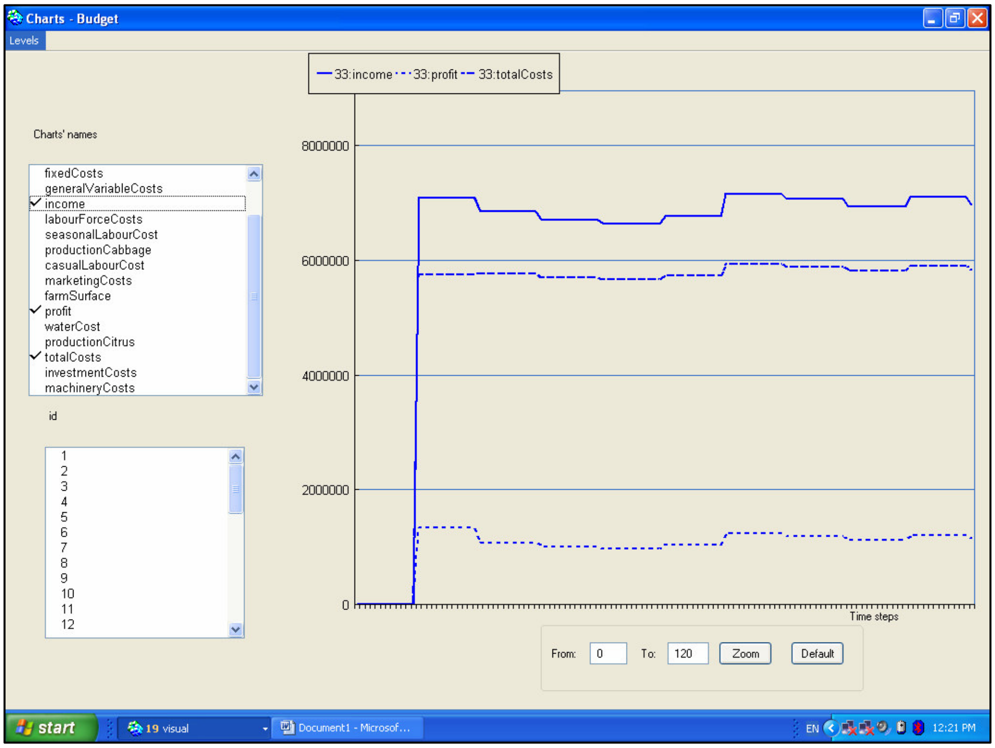

Figure 9 **Annual income, costs and profit of an non-scheduled citrus farmer (ZAR)**

Figure 10 **Presentation of scenarios to the WUA members**

Figure 11 Presentation of scenarios to the WUA members.

Figure 12 Discussion of scenarios among the WUA members.

3 CONCLUSIONS AND RECOMMENDATIONS ON THE USE OF THE KATAWARE MODEL

This report focused on the use of the multi-agent model KatAWARE within a project aimed at facilitating discussions and the negotiations amongst the Kat River WUA members in order to develop a CMP for the area.

After having recapped briefly the main steps of the development of the model, the adoption of the version 1 (V1) of KatAWARE during a workshop with the WUA was presented and discussed.

Some considerations can be drawn from this experience in terms of "lessons" and "perspectives" on the use of KatAWARE in a context of negotiation-support and participatory methods to capacitate the recently-created WUA in setting-up their water allocation strategies.

1) The model is not a decision-support tool in the sense that it does not provide "solutions" for the decision-makers. It proposes a wide set of scenarios which assist local stakeholder to: a) better know about the system at stake; and b) discuss and negotiate around water management and allocation[2]. It is important to observe that several versions of the model were developed during the ComMod process in the Kat. Dialogue and sharing of knowledge among the WUA members and other participants took place during each step of the construction of the model. Throughout the project, focus was on the quality of the process rather than on the quality of the final product, and this is in accordance with the principles of Post-Normal science (Funtowicz & Ravetz, 1991). The construction of a common vision through shared knowledge follows the criteria of constructivism (Detel, 2004; Elby, 2000), from which ComMod is inspired.

[2] Although the quest for realism and good representation of the reality guided modellers to produce a model with sound calibration and consistency with results obtained through other models developed by other research groups on the project, forecast is not the final aim of KatAWARE. For this reason, the not yet operational V2 of the model has a much less 'realistic' interface and is based on the calibration of the RPG instead of the real data that fed V1.

And finally, the iterative nature of the ComMod process and the importance given to the aspect of *learning by doing* are two fundamental characteristic of Participatory Action Research (Liu, 1996; Allen, 2000), which is another pillar of the adopted methodology in this WRC project.

2) KatAWARE was well accepted from the very beginning (prototype) by the local stakeholders. This is probably due to the effort put in and the relatively 'user-friendly' representations of outcomes, based on colour grades and spatial interfaces. Crucial was also the support of the social researchers at Rhodes University from the Catchment Research Group, which introduced the tool to the stakeholders and facilitated every single step of the ComMod process. Another important aspect, which probably facilitated the acceptation of the tool by the WUA, is the experience they have in working within participatory action research projects and with maps and GIS oriented tools. This experience has been generated through several other projects run by the Catchment Research Group that preceded this one in the Kat River Valley.

3) Although the KatAWARE model was generally validated and accepted as a tool for discussing and negotiating by the local WUA, still a certain number of problems can be highlighted:

    a. Some WUA members are slower in following the scenarios and consequently keep quiet during the discussion workshops;
    b. The development and play of the RPG derived from the model was a clear boost for the comprehension of KatAWARE: what if the RPG was not implemented in the process?
    c. The whole process is long and requires a large investment of time and resources. This can represent a constraint for the adoption of a ComMod approach in other catchments.

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Appendix

Installing KatAWARE and downloading/installing Cormas ©

KatAWARE (V1) is a multi-agent model developed on the Cormas © simulation platform.

1) Install Cormas

Cormas can be downloaded free of charge at the web-site:
http://cormas.cirad.fr/en/outil/outchar.htm

The procedure to install Cormas takes place in 2 phases: firstly, it is necessary to install VisualWorks (the programming language freely available on Cincom web site: http://www.cincomsmalltalk.com/userblogs/cincom/blogView?content=visualworks) then Cormas.

VisualWorks is about *60 Mb* (virtual machine and base file) and Cormas is about *8 Mb*.

2) Install KatAWARE

Once the Cormas platform is installed, place the directory called AWAREV0 available in the CD as indicated in the following path:

C:/VW…/cormas/Models/AwareV0

3) Launch KatAWARE

When Cormas is open, go to File menu =>Load=>AwareV0=>Aware V2.st

This will open KatAWARE V1.

From the menu Simulation, the Simulation interface can be opened. This will provide access to the creation of all scenarios indicated in this report. Cormas tutorials and user's guides are available at the web site: http://cormas.cirad.fr/en/outil/outguid.htm.

For further help an Email can be sent to Stefano.farolfi@up.ac.za