High-Level vs. Low-Level Abstraction Approach for the Model and Simulation Design of Ultra-pure Quartz Exploitation in Northeastern Madagascar

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The collection of quartz is a traditional occupation of rural populations in northeastern Madagascar to complement the traditional farming activity, namely the rice crop. In order to assess the possible impact of this complementary activity on the socio-economic situation of the population, and in the context of sustainable development, we have modelled this phenomenon, based on the Multi-Agent System approach, and taken the region of Rantabe, in Northeastern Madagascar, as a case study. The model has been chronologically implemented on two different Multi-Agent System platforms, respectively named Cormas and ADK/RDK, and we have used two different abstraction approaches for their respective implementation and simulation design: high-level (for Cormas) and low-level (for ADK/RDK) abstraction approaches. The main objective of this paper is to discuss, through the presentation of the complete work, the results obtained from the respective two level approaches in order to further advance our ways of thinking as to what approach to choose in a given context.

1 Introduction

1. 1 Quartz exploitation

Ultra-pure quartz constitutes a natural resource long associated with human history (Roche, 1989). More recently, in the twentieth century, it has been exploited to deal with the evolution of many technological innovations, such as sonar for the detection of submarines, frequency control, time measurement, integrated circuits, optic fibres, etc.). In Madagascar, the socio-economic impact of its exploitation on the local population is important (Barthélemy & Orru, 2004). Indeed, an analysis of the quartz network illustrates its societal anchoring and its important role as a non-seasonal activity providing income at a crucial period for the Malagasy family economy (crop breakdown, cyclones, swarm invasions, etc.).

1. 2 A multi-agent model ...

Although the above fact is indisputable, a real evaluation of the impact of quartz in the socio-economic situation of the family is still lacking. Thus, we have attempted, via modelling, to obtain a better understanding of this issue by taking the region of Rantabe in northeastern Madagascar as a case study[(1)]. In this paper, we hereafter formally note this application QZ. This application was developed in order (i) to help in decision making with regard to a strategy of *local* governance for the reduction of poverty and (ii) to design a system of sustainable development[(2)] in northeastern Madagascar.

[1] Rantabe was chosen because it still remains one of the main producing regions of quartz in Madagascar.
[2] As a reminder, sustainable development is related to integrating economic, environmental, social and ethical considerations so that a good quality of life can be enjoyed by current and future generations for as long as possible. The

As for the modelling of QZ, we used the Multi-Agent System (hereafter abbreviated as MAS) approach (Wooldridge 2002). It should be remembered that this approach is often used to model similar phenomena (Rateb and al. 2004), i.e. situations where it is impossible to predict all future changes to a system through a purely mathematical or statistical approach and in which the behaviour of the actors is non-linear and non-deterministic.

1. 3 ...and implementation / simulation

A first version of QZ (Andriamasinoro & Angel, 2004) was implemented on a MAS platform known as Cormas (Le Page and al., 2000), which is a programming environment dedicated to the creation of multi-agent systems with a specificity in the domain of renewable natural-resources management. In the present work, we call QZ-Cormas the version of the QZ application built on Cormas.

A second version of QZ has been more recently implemented on a second MAS platform, known as ADK (Calderoni, 2002). ADK (for "Agent Developer Kit") is a platform developed by Calderoni (2002) with the idea of simulating a society of artificial agents, inspired from animal or human behaviour. Our QZ work is based upon RDK (for "Robot Developer Kit"), the specialisation of ADK to the world of robots that move in a 2D space environment. In the present work, we call Qz-Rdk the version of the QZ application built on RDK.

This paper presents our complete work, set out as follows: firstly, Section 2 summarises our model in order to further clarify the factors involved in our design and the results of our work. Secondly, we explain (Section 3) the two level abstraction approach of the design, before describing and discussing the full results of our work in Section 4. Our conclusions are given in Section 5.

2 Summary of the model

2. 1 Generalities

Modelling the scenario of quartz exploitation can be summarised in Figure 1, which may be explained as follows: as a natural resource, the geographical location of quartz can be anywhere in the physical environment. The persons responsible for quartz searching and collecting are *farmers*[(3)]. As and when the quartz is transferred from actor to actor, a step of transformation (e.g. pre-grinding, purification) occurs, leading to a progressive decrease in the quartz weight. In Figure 1, we assume that, initially, a farmer has found 100 *kg* of quartz. The farmer's family sells the remaining *80 kg* of the quartz to a *collector* who, in turn, searches for *conveyors* in order to deliver the quartz (remaining: 68 *kg*) to the Rantabe *exportation company*. The 61.2 *kg* resulting from the company handling is then shipped from Rantabe to *Tamatave*, the only location from which the quartz may be exported. Inversely, after an exportation process, a distribution of the financial ratio of the quartz value occurs (we present here the FOB (Free On Board) value).

Note that the *state* agent represents the Malagasy State, and *community* corresponds to the local region community (i.e. Rantabe). This region is composed of many *villages*.

The delimitation set for the model (see the bold line in Figure 1) means that none of the area on the right of the line is taken into account in our modelling. Indeed, we operated at a micro-economic level, namely by studying the evolution of the population in the locality of Rantabe. The exportation part is mentioned only in order to situate the real-life situation. This aspect will be investigated in future work.

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broad concept of sustainable development gained prominence after the publication of the so-called Brundtland Report 'Our Common Future' (WCED, 1987). In the present work, our simulations, with respect to this concept, last at least 25 years in order to provide an intergenerational dimension to the study.

[3] The reason for the term "farmer" is because the persons concerned are essentially farmers, the quartz exploitation being only a complementary activity.

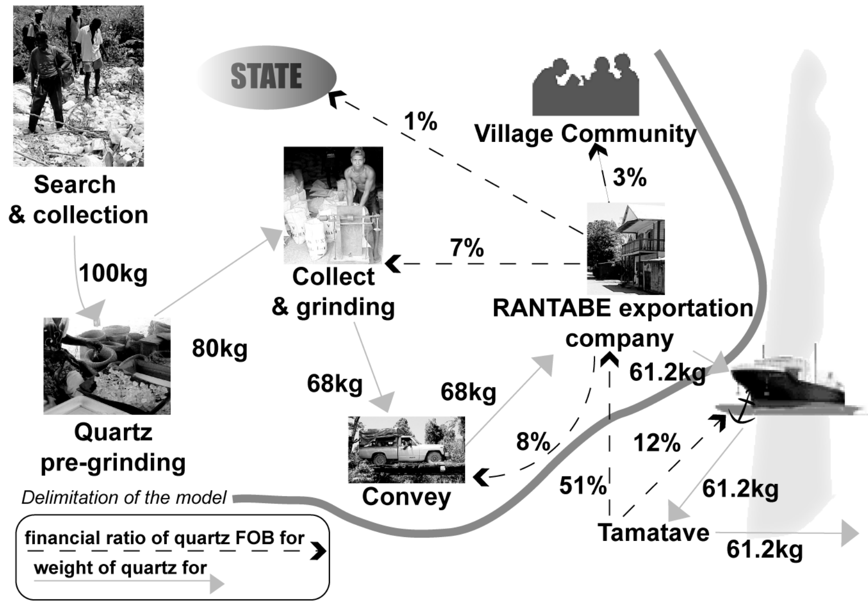


Figure 1: Global view of the Qz scenario

2. 2 Economic factors of the model

2. 2. 1 Preamble

Given that rice is the basic food for the Malagasy population, we adopted the fact that the economic unit of the model is *stock of rice* instead of *money*. This stock, noted `sor`, is generally measured in *kg*. The `sor` is decreased by the consumption of rice but is increased by the sale of quartz and the results of the rice crop activity.

The value of the quartz is measured from the ratio (*weight of quartz/weight of rice*), noted ρ. This notation means that the price of quartz is ρ times higher than that of rice.

2. 2. 2 The main factors

Overall, the main keys we used for evaluating a family situation were its *capital*, its economic *status*, and its *goal*.

The capital

In practical terms, this is represented by the current value of the family `sor`. The evolution of the capital depends on the productivity given by the crops and the quartz activity.

The status

Each family has a status, noted σ_{family} which can take either the value `poor`, `middle` or `rich`. Status is determined by the months of subsistence of a family (noted μ_{family}), Equation (1) in which Δ_{cons} is an approximate average of `sor` consumed on a daily basis by a member, $\eta_{members}$ the number of family members, and the number 30 comes from the assumption that 1 month = 30 days.

$$\mu_{\mathsf{family}} = \frac{\mathsf{sor}}{\eta_{\mathsf{members}} * 30 * \Delta_{\mathsf{cons}}} \tag{1}$$

Then, given μ, the parameter σ can be deduced via Equation (2).

$$\sigma = \begin{cases} \mu < 5 \Rightarrow \sigma = poor \\ 5 \leq \mu < 25 \Rightarrow \sigma = middle \\ 25 \leq \mu < 50 \Rightarrow \sigma = rich \end{cases} \quad (2)$$

The values 5, 25 and 50 in Equation (2) are currently arbitrary.

There are also important parameters, all measured in *kg*, which closely depend on σ. These parameters are important for the socio-economic management of the family, as we will see later. For a given σ, their values are *fixed* independently of the families. We have:

- `sth`, which is the *satisfaction threshold* for a family. This variable indicates the value of `sor`, which allows a family to claim if it is satisfied or not, given its σ. In fact, it happens that a non-rich family may consider itself as satisfied, even if it is not rich. In many underdeveloped countries, we can for example find boys who go to school with no shoes, but who feel happy since they quite rightly have a home and eat three meals a day. These factors play a role in giving them life satisfaction. Inversely, rich families may not be satisfied, despite their wealth. These situations are further clarified by the notion of goal, given below.
- `fth`, which is the *foundation threshold* of a family. This is the value of `sor` that a family should minimally have so that a member can start a new family (via a wedding).

The goal

Given its σ, the goal γ of a family depends on its `sor`, its `sth` and its `fth` (see Figure 2 for the evaluation). The goal is important, since it determines the actions α (in the form of strategy[4]) to be adopted by the family. Thus, if γ changes, α also changes[5].

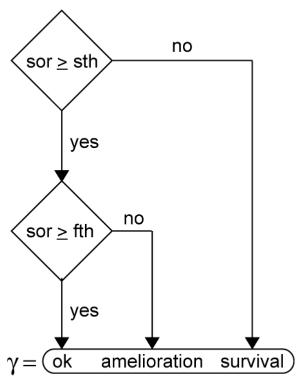


Figure 2: Determination of the family goal

From the worst to the best scenario, γ can take either the values `survival`, `amelioration` or `ok`.

2. 3 Social factors of the model

These mainly concern the description of parameters that affect the dynamic of families and, by extension, that of the population. Based on the context of sustainable development, that is, the intergenerational study, the parameters we considered were (i) the *age* of the agents, (ii) the family *wedding* and *birth* and (iii) the *death* events. We will not further detail the way they are structured, since this structure is not related to the results obtained in this paper. Suffice to say that the determination of the value of most of

[4] The concept of strategy will be explained in Section 2. 4.

[5] In agent paradigm, γ is called *motivation* and α the resulting actions.

these social parameters is based on the previously defined economic factors. In addition, we opted for 5 age classifications: [0-15],]15-30],]30-40],]40-55] and >55. During family initialization for a simulation, the age is generated in a random manner. The idea was to initially have a realistic distribution between young and old people.

2. 4 Family behaviour: strategies and actions

Depending on its goal, each family decides, on a daily basis, on the activity of its members. To do this, it has the choice between several strategies. A strategy is composed of actions α consisting in sending members to either the rice crop (if it is the season), to the vanilla or clove crops (if any exist and also if it is the season), and searching for quartz (see Figure 3).

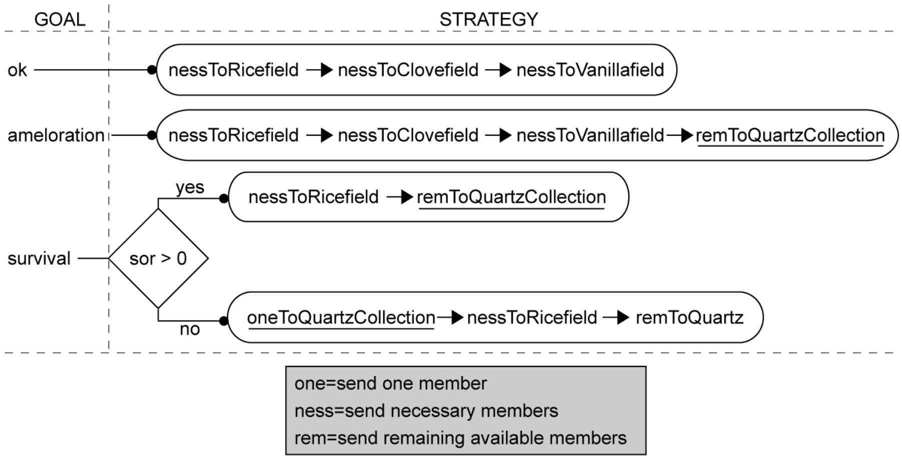


Figure 3: Diagram showing the family strategies. The quartz collection is introduced as a strategy for survival

The family strategies aim at defining priorities between the allocation of actions. Structurally, we built them with respect to what actually happens in Rantabe, that is, the rice crop still remains the main activity for the local population. A priori, the *necessary*[6] members should then be allocated to the rice crop first. However, the more $\gamma \rightarrow$`survival`, the more the collection of quartz takes place as a priority action for a family (see underlined actions in Figure 3). This is the reason we name the quartz collection a *strategy for survival.*

The clove and vanilla crops remain a secondary activity after the rice crop. Family members work them only if (i) the family has the corresponding crop field, (ii) it is the crop season, (iii) the *necessary* members are already sent to the rice crop (also if it is the season), and (iv) $\gamma_{family} \neq$`survival` and, in that case, these crops are always worked *before* the quartz collection.

3 The two levels of the abstraction approach

The existence of the two levels for the design of the previously described model was mainly due to the general conceptual choice and competency of the respective modeller/ developer of `QZ-Cormas` and `QZ-Rdk`. Let us call them `Dev-QzC` and `Dev-QzR` respectively.

[6] In this study, the value of "necessary" turns around 1 and 2 (members), according to the surface crop.

3. 1 The approach for designing Qz-Cormas

`Dev-QzC` is a non-computer scientist person but possesses skills in MAS modelling and computer programming. The first concern of `Dev-QzC`, compared to our work objective, was to collect as many simulation results as possible in order to perform his analysis. Thus, for this work, `Dev-QzC` adopted what we call a *high-level abstraction approach* (noted `high_app`) for the `Qz` design that we directly present as a function of its limitations and advantages.

3. 1. 1 Limitations

Some parameters from this approach present the following characteristics:

- *temporary*: the behaviour of the `QZ-Cormas` agents is directly pre-programmed at application level (based on `if-then` rules), i.e. it is valid for `Qz-Cormas` only.
- *static*: the time management of the `QZ-Cormas` is programmed according to a static structure like 1 day = 6hours, 1 month = 4 weeks and 1 year = 12 months.
- *simplified* : most parameters of the model such as *individual rice consumption* are represented by averages only, without taking into account individual, detailed parameters such as `age` or `sex`.

This approach does not contribute to the reusability of the underpinning platform for another application. Additionally, the process must be handled carefully because too much abstraction may lead to less accurate representation of the real world.

3. 1. 2 Advantages

One main advantage of this approach is that the resulting simulation runs are faster since there is less computation to be performed by the processor, due to the `if-then` rules, and also due to the particular focus of the implementation on `QZ-Cormas`. One important interest of having a faster simulation is that since our context is sustainable development, this approach allows `Dev-Cormas` to make as many simulations as possible in order to obtain a quick idea of the robustness of the system.

3. 2 The approach for designing Qz-Rdk

Unlike `Dev-QzC`, `Dev-QzR` is a computer scientist researcher. Although, obviously, he also has the aim of making as many simulations as possible and collecting the results in the same way as `Dev-Qzc` did, he, in addition, has the concern of improving the conceptual aspect of ADK/RDK, particularly at two levels:

- managing, as far as possible, the behaviour of the system at generic level. This idea is motivated by a possibility of reusing it for another application having the same context and scale (as is the objective in our department's research).
- being able to represent a system as detailed as possible in order to cover all possible situations.

Thus, `Dev-QzR` adopted what we call a *low-level abstraction approach* (noted `low_app`) for the `Qz` design. As with `high_app`, we directly present `low_app` via its advantages and limitations.

3. 2. 1 Advantages

Some parameters from this approach present the following characteristics (which are actually the opposite of the limitation of `high_app`):

- *permanence* : the agent's behaviour is currently managed by a generic engine in RDK, based on the notion of natural motivations, that is, motivations based on natural needs (hunger, social needs, self-preservation, etc.). It is valid for any application other than Qz-Rdk.

- *dynamic:* the time complies with the dynamic Gregorian calendar structure. The number of days in a month, for example, depends on the month itself (e.g. January, February, etc.). Leap years are also taken into account.
- *detailed* : most parameters of the model such as *individual rice consumption* are determined according to parameters like age or sex.

3. 2. 2 Limitations

The limitations of low_app are also actually the opposite of the advantages of high_app). In fact, in multi-agent research, performing a low-level abstraction approach, especially at a generic level, is a recommended improvement. However, a first consequence of this situation is a problem of performance, especially when the number of agents increases (which is the case for Qz, as we will see later). When simulating applications, the computational cost of the system evolution increases since a "transfer" of behaviour management was made from users to agents and by extension, to the computer in which the agents are simulated. At each cycle of the simulation, represented by a *time step* noted θ, each agent has to re-evaluate the next micro-action it has to execute since there is no longer a pre-programmed action. In Qz, these constraints mean that if Dev-QzR wants to have as many results as soon as possible, he has (i) to decrease the number of simulated agents in the system and (ii) to increase the θ *timeunit*. Step (i) requires him to select the appropriate agent to be removed without affecting the overall result he wants to obtain and (ii) aims at finding the maximum value of θ beyond which data start to be lost.

Table 1 gives examples of differences (choices and/or consequences) due to the two level abstraction approaches related to the Qz application.

Parameter	**QZ-Cormas (High-level design abstraction)**	**QZ-Rdk (Low-level design abstraction)**
One member's daily consumption	0.7 kg	0.7 kg/day/member if age ≥10 (0.7 kg*age*random)/day/member if age <10
Number of possible villages during the simulation	6 villages	2 villages (consequence of a weak performance)
Initialisation of families (at maximum)	20 families/village & 11 members/family	20 families/village & 5 members/family (consequence of a weak performance)
Simulation time step	1 hour	27 minutes (due to more computation at a generic level)
Simulation start date	At t=0	At t=0 of the 1^{st} of January 20xx where 20xx is the current year in the real world from which the simulation starts

Table 1: Example of differences (choice and/or consequences) due to the two methodologies of level abstraction

3. 3 The dynamic in the two levels

Qz-Cormas was developed before Qz-Rdk. In order to make progress in analysing and testing the Qz application only, we added some other concepts when designing the Qz-Rdk. It particularly concerns *the time for evaluation*, by the system, of the diverse socio-economic parameters described previously. Table 1 summarises the corresponding differences between Qz-Cormas and Qz-Rdk. We here introduce a more *reactive* and dynamic behaviour for Qz-Rdk, in order to test an alternative to the pre-programmed approach adopted in the initial Qz-Cormas. This notion of *reactivity* is a behavioural hypothesis we have introduced because we think it may also influence the general evolution of the population.

Parameter	Qz-Cormas	Qz-Rdk (more reactive)
Actions and strategies (α)	Daily	Daily
Family status (σ)	1 month (for all families)	1 day (for rich families), 15 days for middle class families, 1 month for poor families
Births (β), deaths (δ) and weddings(ω)	At the beginning of every year for all families	Also every year but not at the same time for each family. The evaluation is distributed throughout the year in a random manner.
Goal (γ)	Yearly	In a random manner throughout the year

Table 2: Periods used for the evaluation of some parameters by the system

4 Experiments and discussion

4. 1 Example of simulation results

Figure 4 shows a representative result[7] of the *average* of the `sor` (noted `ASOR`) per family status when ρ increases (here, 1, then 5, then 7). It allows us to relatively compare `Qz-Cormas` (Figure 4-a) and `Qz-Rdk` (Figure 4-b) resulting from our two respective approaches.

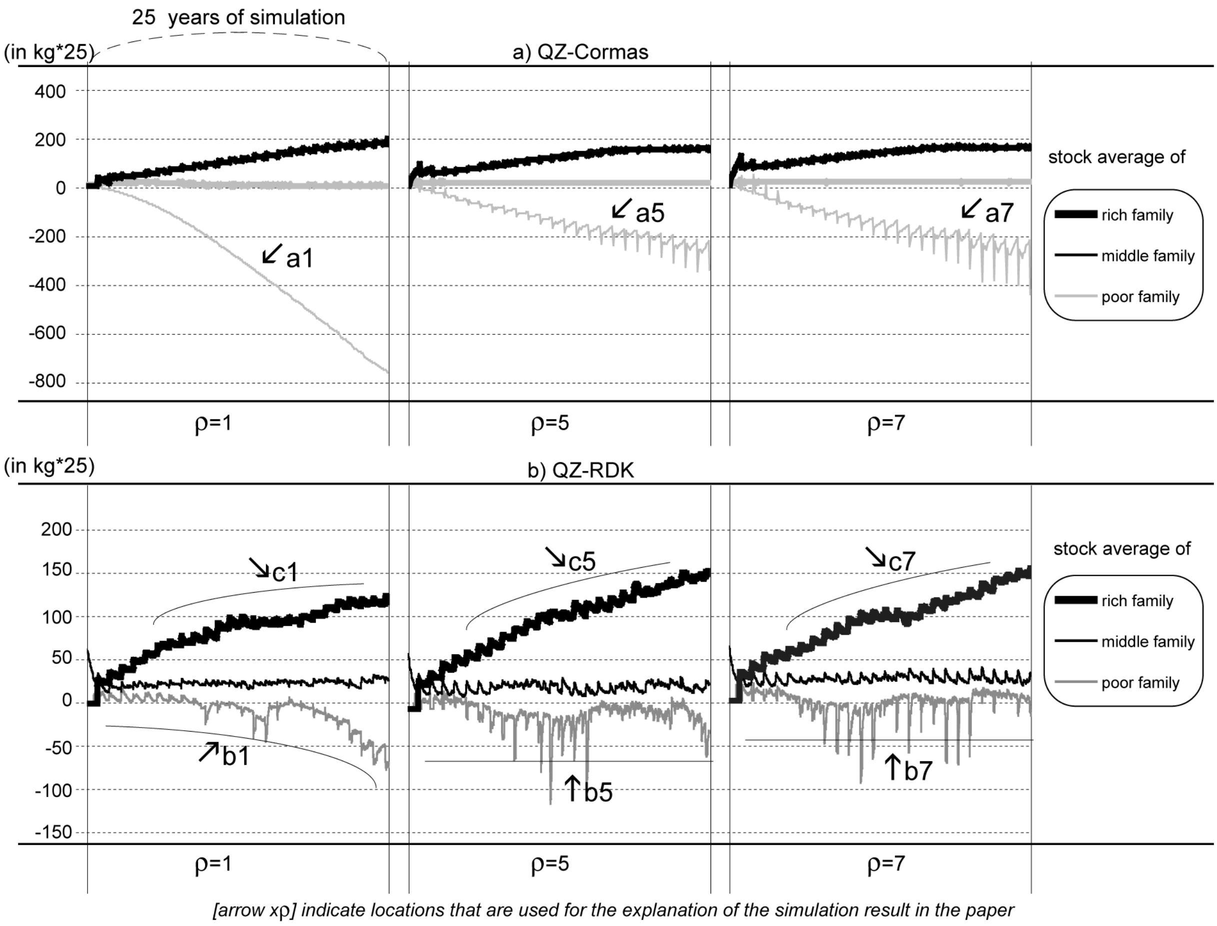


Figure 4: Evolution of the ASOR per family status

[7] This means a general result after many simulations with the same set of input parameters.

4. 2 General observation

We can see in Figure 4 that, even if similar tendencies exist in the results, the two approaches do not show the same degree of impact on the ρ-increase. On the one hand, the variation in the tendency is *strong* from [↙a1] to [↙a5] and is *weak* from [↙a5] to [↙a7], while from [↗b1] to [↑b7], this variation in the tendency is always *weak*. On the other hand, in `Qz-Rdk`, the ρ-increase also starts to affect rich families (cf. from [↘c1] to [↘c7]). To summarise, the families modelled with `Qz-Rdk` are “richer” than those modelled with `Qz-Cormas`.

4. 3 Analysis

4. 3. 1 With regard to the evolution of the plot

According to our own analysis, the differences between the plots in Figure 4-a and Figure 4-b can be explained by many factors. Firstly, the reason the `Qz-Rdk` population is “richer” than the `Qz-Cormas` population is the introduction of the concept of reactivity in `Qz-Rdk`. Indeed, the richer a population, the greater its concerns about its status and, as a result, the probability for being poor decreases, unlike in `Qz-Cormas`, in which all status is evaluated at the same time, namely monthly (cf. Table 2, line 2). In addition, the number of agents in the two simulations is different, that is, it is easier to become rich with few populations (cf. Table 1, lines 2 and 3).

4. 3. 2 With regard to the form of the plot

One may wonder why, in all of the simulation figures, the evolution of the serrated form of the curves in `Qz-Cormas` is more “regular” than that of `Qz-Rdk`. We can put forward the following arguments:

- the difference in the management of the time can be a source of difference: in `Qz-Cormas`, it is more static that in `Qz-Rdk` (cf. Section 3. 1. 1, Section 3. 2. 1, and Table 1, line 5).
- likewise, the time for evaluating different parameters (birth, death, goal, etc.) is also a possible reason for the difference (cf. Table 2, lines 2 and 3). Referring to the births and deaths for example, the moment that a population increases/decreases is not the same for the two approaches, having short and medium-term impacts on the evolution of the family `sor`.
- to a lesser extent, we can also imagine that `Qz-RDK` goes into some details, such as the level of hunger of each family member while `Qz-Cormas` works with the concept of average only. This respective choice affects the value of the family `sor`, since the capacity of absorption of rice per family is different.

4. 4 Discussion

4. 4. 1 What level of abstraction approach to adopt?

The present work shows that the choice of the initial abstraction approach that a designer may adopt in modelling a complex system is important. Thus, there is no simple answer to the above question. Nevertheless, we will attempt to provide some initial elements that could help in answering this question.

Beforehand, it should be recalled that according to Section 3, we performed our study based on the following criteria: the *time*, the *behaviour* and the *detail level* of the modelling. From these criteria, we can identify two situations:

- the limitations of the `Qz-Cormas` design (cf. Section 3. 1. 1) constitutes advantages for the `Qz-Rdk` design (Section 3. 2. 1), and vice-versa (cf. Section 3. 1. 2 and Section 3. 2. 2 respectively).
- the simulation results are nearly different.

In our opinion, answering the above question firstly involves considering the following factors:

- the nature of the user. Remember the case of `Dev-QzC` and `Dev-QzR` in Section 3, who have common but also different objectives, driven by their respective skills.
- the status of the tool to be used for the simulation. This mainly influences the simulation level of either approach (implementation, initialisation and running). Note that, currently, most tools used for land use management such as Ascape, Repast, Cormas, etc. still require a minimum level of skill for programming, according to the classification in (Parker and al., 2002).
- the current purpose of the modelling: is it for internal purposes (i.e. intended only for the expert/scientist) or for external purpose (i.e. intended for entities such as stakeholders, who are generally pure tool users with virtually no programming skills).
- And, last but not least, the choice is also oriented by the number of data currently available of the modeller. Some modellers make abstraction of some situations due to the lack of data used for analysing these particular situations.

4. 4. 2 Future trends and proposals

One major aim of all studies related to resource management and environment is to try to answer the needs of society. Thus, while not disregarding the difficulties brought about by the above factors, we propose that the current progress should be the design, *in conjunction with stakeholders*, of (i) a model, (ii) a simulation tool, and (iii) a useful methodology that can aid in the construction of social simulation models as decision-making tools. Such a participative approach is important, since it gives the modeller a better picture of the real society, with a more accurate view than that of experts/scientists. Works like (Ramanath and Gilbert, 2004) are important references for this purpose.

This proposal involves the orientation of all design to the needs of the local population and the stakeholders (i.e. non-specialist users), rather than the expert/scientist users. Indeed, the latter can generally manage the former resulting tool while the inverse is not true.

4. 5 Open discussion: the representation of the environment

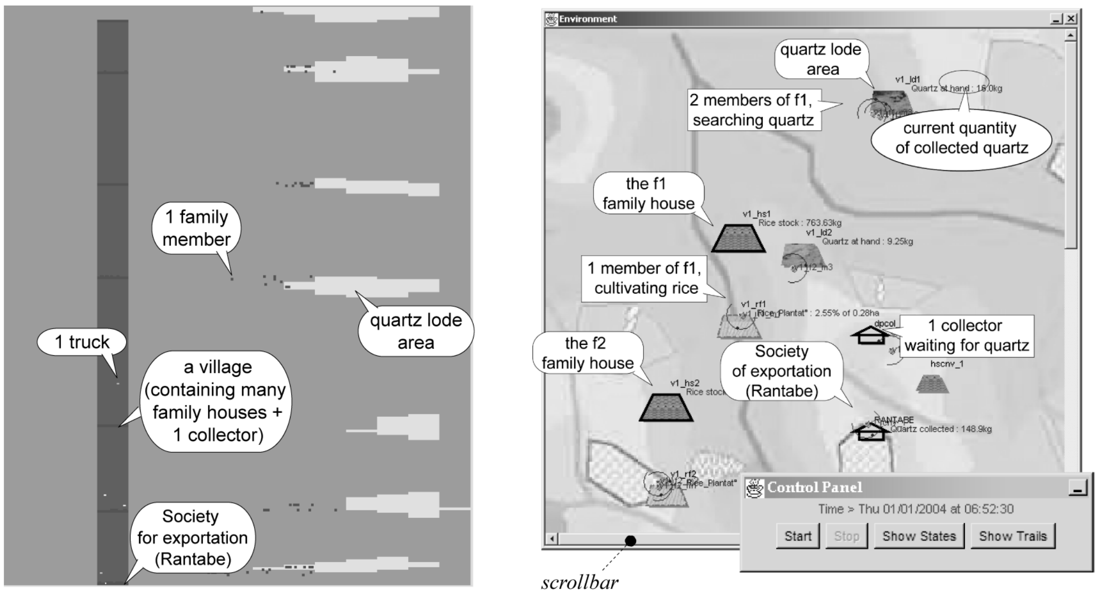
At the end of this paper, we would like to recall the discussion among researchers about the representation of the environment, since we noted this during the respective development of `Qz-Cormas` and `Qz-Rdk`, for example, about the spatial representation of the resource. In particular, we believe (but the discussion remains open) that it may be also related to the high/low level approach of an environment design. However, we have not included it as a part in the main sections of this paper since we think that it has no real impact on the simulation result (for the case of this particular study only), but it should be considered for discussion for a future application.

This open discussion involves the analysis of the environment architecture. In fact, the latter is divided into two main groups: a discrete and a continued-based architecture (noted respectively `da` and `ca`). This issue is related to the following question: into how much detail should one go to represent the environment?

To further our ways of thinking about this issue, we show in Figure 5 the difference we have seen between the environment of `Qz-Cormas` (in a `da` form) and `Qz-Rdk` (in a `ca` form). In fact, it seems that `da` is a "member" of the high-level abstraction approach and `ca` is a "member" of the low-level abstraction approach. The figures present family members (e.g. `f1` and `f2`) going to the quartz lode area or the rice field, depending on their strategy.

As a reminder, the `ca` and `da` representations have the following (non-exhaustive) features:

- `da` allows the user to obtain quickly enough what he wants to represent, but spatial information (for example a view of the exact delimitation of a resource) is less precise because `ca` is based on cells, i.e. in a geometrical term, in a form of a square or a pixel.



a) the environment of `Qz-Cormas` with the following features:
- the internal elements are represented in a cellular form
- the environment architecture is discrete
- possibly shows a total view of the simulation
- high-level abstraction approach (less precision of the reality form)

b) the environment of `Qz-Rdk` with the following features:
- the internal elements are represented in a vectoriel form
- the environment architecture is continued
- generally shows a partial view of the simulation (cf. the scrollbar)
- low-level abstraction approach (more precision of the reality form)

Figure 5: The two main forms of the representation of the environment design

- `ca` gives better detail of what one wishes to represent, but is more difficult to design because the objects (e.g. the resources) in the environment generally take geometrical forms such as a circle, polygon, etc. and it involves more a complex algorithm during its manipulation, whereas `da` is in the form of (a generally two dimensional) matrix, involving easier data management.
- as a result of the above two situations and, in simulation terms, the performance of a system with `da` may be weaker than that with `ca`. Indeed, the computation of the spatial presence of resources, for example, takes more time with `ca`.

Note that, currently, most tools like Cormas, that used by the Fearlus model (Izquierdo and al., 2003), etc. adopt `ca` while robot-based tools like ADK/RDK or MadKit (Ferber and al., 2000) adopt `da`[(8)].

5 Conclusions

This paper presents our comparison of two approaches about the model and simulation design of ultra-pure quartz exploitation in Rantabe, in northeastern Madagascar. The idea was to find and to evaluate the advantages and limitations of both approaches for modelling this type of activity (according to the criteria we have proposed) in order to progress our way of thinking on what approach to choose in a given context. On the whole, it is difficult to give a precise answer to this issue. However, we think that the current trend is the elaboration and discussion of this kind of work with stakeholders. Thus, a modeller should progressively implement a "normal" user-oriented tool rather than an expert/scientist oriented tool. It means improving the participative approach during the design of the model and the resulting tool. One of the major perspectives of this work would then be to build up a methodology that can aid in the construction of social simulation models as decision-making tools with such stakeholders.

As an additional perspective of the work, we plan to further investigate the impact of quartz exploitation on the general quantity of this resource in Rantabe, in order to continue to pursue our efforts in

[8] However, we note that the latter are less well chosen when it concerns the management of resources.

sustainable development research related to mineral resources.

References

Andriamasinoro F. (2004). *Modeling Natural Motivations into Hybrid Agents.* In Proceedings of 4^{th} International ICSC Symposium on Engineering Of Intelligent Systems (EIS 2004), Island of Madeira, Portugal, February 29 – March 2, 2004, in CD-Rom, and Abstract in International Computing Sciences Conferences Press, (ISBN 3-906454-35-5), p. 66.

Andriamasinoro F., Angel J.M. (2004), *Predicting the Impact of the Value of the Quartz on the Dynamics of Rural Population in Madagascar: A Multi-agent System Experimental Approach.* Abstract in Proceedings of the 20th Colloquium of African Geology (CAG 20), Orléans – France, June 02 - June 04, p.47.

Barthélemy F., Orru J.F. (2004), *Le quartz ultra pur de Madagascar, contribution d'un artisanat minéral au développement local et durable.* In CD-Rom, and Abstract in Proceedings of the 20th Colloquium of African Geology (CAG 20), Orléans – France, June 02 - June 04, p. 63.

Calderoni S. (2002), *Ethologie Artificielle et Contrôle Auto-Adaptatif dans les Systèmes d'Agents Réactifs : de la Modélisation à la Simulation.* PhD Thesis, University of La Reunion, 175 pages.

Ferber J., Gutknecht. O., Michel F., (2000). Madkit : Une expérience d'architecture de plate-forme multi-agents générique. Rapport de recherche LIRMM.

I.R. Izquierdo, N.M. Gotts and J.G. Polhill, (2003), "FEARLUS-W: An Agent-Based Model of River Basin Land Use and Water Management" Paper presented at "Framing Land Use Dynamics: Integrating knowledge on spatial dynamics in socio-economic and environmental systems for spatial planning in western urbanized countries", International Conference 16-18 April 2003, Utrecht University, The Netherlands.

Le Page, C., Bousquet, F., Bakam, I., Bah, A., Baron, C. (2000). *CORMAS : A multiagent simulation toolkit to model natural and social dynamics at multiple scales.* "The ecology of scales", Wageningen (the Netherlands), June 27-30. Also visible in *http://cormas.cirad.fr/index.htm.*

Parker C. D., Berger T., Manson M. (Eds.) (2002). "*Agent-Based Models of Land Use and Land-Cover Change* ". Report and Review of an International Workshop, October 4-7, 2001, Irvine, California, USA. LUCC Report Series N ° 6.

Ramanath, A.M. and Gilbert, N., (2004), "The Design of Participatory Agent-Based Social Simulations". in Journal of Artificial Societies and Social Simulation vol. 7, no. 4, October 31

Rateb F., Pavard B., Merelo Guervos J.J., Bellamine-BenSaoud N., Garcia Arenas, M.I. 2004. Modelling Malaria with Multi-Agent Systems. In Proceedings of 4th International ICSC Symposium on Engineering Of Intelligent Systems (EIS 2004), Island of Madeira, Portugal, February 29 – March 2, 2004, in CD-Rom, and Abstract in International Computing Sciences Conferences Press, (ISBN 3-906454-35-5), p. 152.

Roche H. (1989). *Technological evolution in early hominids. OSSA*, vol. 14: 91-98.

WCED (World Commission on Environment and Development), (1987). *Our Common Future. Oxford University Press*, Oxford.

Wooldridge M. (2002), *An Introduction To Multiagent System*, John Wiley & Sons, March, 340 pages.