Practical Approach To Agent-Based Modelling

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2.4. Practical Approach To Agent-Based Modelling

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Representing a real system in all its complexity in order to measure its possible evolutions, or to conceive development solutions that are adapted to it, is one of the challenges of current computer modelling, particularly of agent-based modelling. This approach, which complements classical analytical methods, allows us to incrementally conceive models whose dynamic is the result of interactions between computer representations of the entities in a modelled system (players, institutions and environment, biological or abiotic entities). These models are then used to support a "virtual" experimental method – making use of simulations – where the resulting dynamics can be studied with all the necessary details, and where interaction with the user is encouraged.

This workshop is organised around the GAMA modelling platform, *Gis and Agent-Based Modelling Architecture*, see http://gama-platform.googlecode.com, developed by the IRD and its partners and a tutorial developed from a role-playing game about water management, "Wat-A-Game", developed by the CIRAD, see http://sites.google.com/site/waghistory/home. Its aim is to allow trainees to discover agent-based modelling and its potentialities, by conceiving and progressively improving a group of more and more complex models whose subject is water management, by a team of players: administrators, water-using activity managers, monitoring services, etc.

Different subjects are progressively addressed, from the installation of GAMA to the conception of different "realist" human behaviours, against a background of the coupling of heterogeneous social and environmental data, allowing us to generate rich and complex scenarios. A part of the workshop is devoted to the conception and writing of these models, but a large part is reserved for debate, particularly about the choices of conception and representation made during the proposed tutorial. The last day allows participants to propose, test and compare different representation solutions of the decision mechanisms in the model.

(Transcript)

Day 1, Monday 16th June

2.4.1. Modelling Applied To Water Management

[Alexis Drogoul]

We are going to work together on the building of agent-based models devoted to an application of water management. We shall take some time explaining our objectives to you and how we are going to achieve them. Next, we shall ask you to introduce yourselves and specify your research/study objectives and the reasons for your participation in this workshop. We should like to know which situations you would like to model, and whether or not you have had any previous computer programming experience.

> *Presentation of trainers and trainees (see trainer biographies, list of trainees inserted at end of chapter)*

Your experience and expectations in modelling terms are particularly varied, but few of you are familiar with this technique.

We are going to accompany you gradually so as to allow you to call upon your own research problematic. To do this, we are going to follow agent-based methodology that allows incremental modelling. It entails building models by beginning with basic entities and progressively adding to them: component additions and modifications for existing components in order to obtain more complex models.

After a general presentation, we shall start building our models this afternoon. Our ambition is to immerse you directly into the practice, so that you will become autonomous as the week progresses; you are going to have to learn to use computer tools and language.

You can imagine that the model is a play with scenery, actors, scenarios and interactions. The two first days will be devoted to the building of the scenery. Next we shall introduce the actors who will have their own behaviour, autonomy and maybe knowledge. The roles of these actors will not be completely written; you will intervene on the models using computer tools to describe the actors' behaviours, for example, planning and strategies, in such a way as to be able carry out experimentations and compare them. At the end of this workshop, you will certainly not all have the same play or the same scenario.

Two volunteers amongst you will be responsible for the feedback on your work on Saturday: taking notes of the training content, collecting of other trainees' impressions and particularly problems that may not have been voiced.

> *The GAMA programme is installed on the trainees' computers. The training sheets and the geographical information dossiers are transmitted to the participants.*

Benoit Gaudou is now going to give you a succinct presentation of the GAMA programme and the "Wat-A-Game" model, which was not originally a computer model.

Box 16 Introduction to GAMA

Software platform dedicated to building spatially explicit agent-based simulations

- Generic: can be used for a wide range of applications

- Developed under GPL/LGPL license: free

- Integrates a complete modelling language (GAML) and an integrated development environment: allows modellers (even non computer-scientists) to build models quickly and easily

- Developed in JAVA: easy to extend in order to take specific needs into account

- Integrates tools to analyse models: parameters space exploration and calibration of models

GAMA

1.5

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http://gama-platform.googlecode.com

Sources: Authors' construction.

[Benoit Gaudou]

The MAELIA project, previously spoken about in the plenary session, also uses the GAMA platform, which allows us to carry out agent modelling using spatially explicit models. It is a generic platform that may be used to deal with diverse types of problems: Alexis spoke about issues of segregation; I presented a questioning of water flows, but we could also have spoken about problematics concerning land development or the propagation of illnesses for example. We are going to focus upon water management.

One of GAMA's characteristics is that it is an "open source" programme. You can download the source code, that is to say the whole programme that allows the elaboration of the software. You have the possibility of adapting and improving it depending on your needs. This software programme was developed to be used by individuals who have not yet completely mastered the classical programming languages; it contains a simplified language adapted to the construction of multi-agent models: GAML *(Gama Modelling Language)*.

You are going to write your own model and try to make it match reality as much as possible.

Box **17** Introduction to GAMA (2)

Strengths of GAMA

- Supports the development of quite complex models

- Seamless integration of geographic data and GIS tools with agent-based models

- Integrates a methodological approach to define multi-level models

- Integrates high-level tools: multi-criteria decision-making tools, clustering functions, statistical operators…

- Easily extensible thanks to its open architecture, which relies on two legacy Java technologies: OSGI plugin framework and Java annotations

GAMA

1.5

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http://gama-platform.googlecode.com

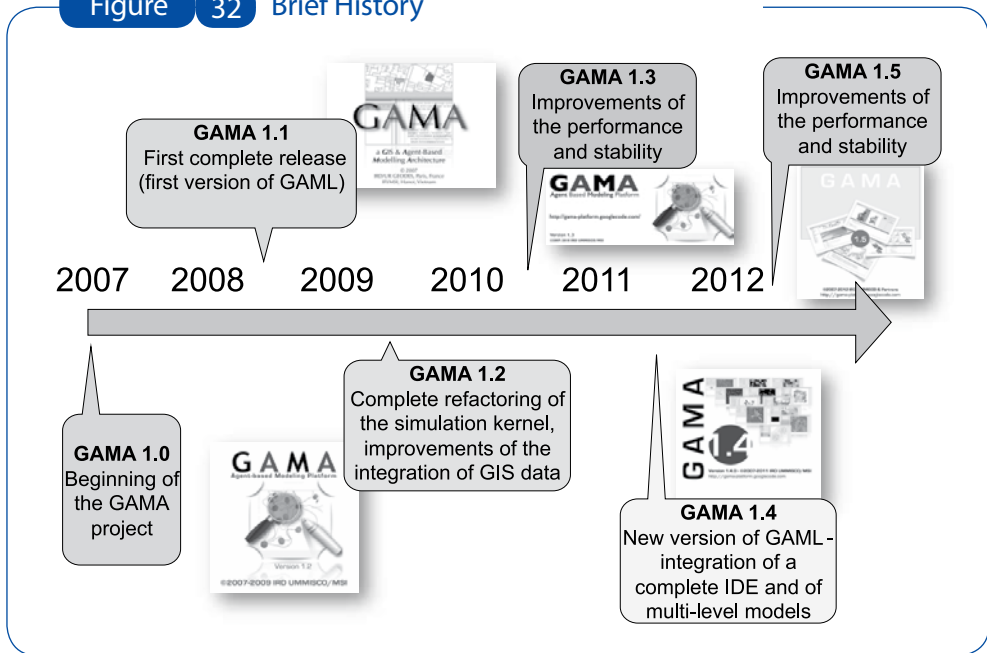*Sources: Authors' construction.*

What are GAMA's strong points?

One of the targets of the programme is to build complex models that allow us, by taking on board numerous data, to appreciate the behaviours of the developed agents and observe the realist models.

The integration of geographical data and the method for developing the multi-scale models remain relatively simple – each level can correspond to agents or to entities endowed with behaviours. GAMA allows us to easily manage the interactions between these different levels.

With the aim of making more complex and expressive models, the programme is endowed with tools from mathematics, statistics and artificial intelligence. It notably includes *clustering* and decision algorithms.

Figure **32** **Brief History**

GAMA 1.1
First complete release
(first version of GAML)

GAMA 1.3
Improvements of
the performance
and stability

GAMA 1.5
Improvements of
the performance
and stability

2007   2008   2009   2010   2011   2012

GAMA 1.0
Beginning of
the GAMA
project

GAMA 1.2
Complete refactoring of
the simulation kernel,
improvements of the
integration of GIS data

GAMA 1.4
New version of GAML -
integration of a
complete IDE and of
multi-level models

Sources: Authors' construction.

A first version of GAMA was developed in 2008-2009 with a more structured and less intuitive language. The Geographical Information Systems (GIS) were added in 2009-2010, and the multi-level approaches and new modelling languages in 2011.

To conclude this introductory part, let us indicate a certain number of available resources where you can download different versions and recuperate GAMA sources.

Box 18 More Information

❖ Blog
 http://gama-platform.blogspot.fr

❖ **Web site of the project**
 http://code.google.com/p/gama-platform/

❖ Documentation
 http://code.google.com/p/gama-platform/wiki/Documentation
❖ Mailing lists
• General mailing list
 https://groups.google.com/forum/?fromgroups#!forum/gama-platform
• Developers mailing list
 https://groups.google.com/forum/?fromgroups#!forum/gama-dev

Sources: Authors' construction.

The aim of this tutorial is to make you familiar with GAMA by modelling a water catchment area, the water dynamic and interacting human activities. It will then be possible to evaluate the influence of these activities from a quantitative and qualitative point of view, particularly in terms of pollution. In this water catchment area scene we shall imagine different water management, activity management and policy strategies, etc.

To do this we have chosen a rather simple model, "Wat-A-Game", https://sites.google.com/site/waghistory/wag-courses.

Box 19 WAT-A-GAME: Introduction

WAT-A-GAME (WAG) is an open toolkit and a method based on simple bricks for designing and using participatory simulations (*i.e.* role playing games) for water management, policy design and education.

Adaptable to:
- Represent any kind of basin and any kind of situation
- Various actors for various types and levels
- Sessions can be self-designed by the players
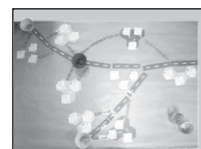
Sources: https://sites.google.com/site/waghistory/wag-courses.

"Wat-A-Game" (WAT) is a game that allows field players to represent their catchment area and to interact, to see how the water flows and examine how to implement management policies. The game consists of schematic elements: streams and rivers, multiple activities, etc. The idea is to have a base on which any catchment area may be represented and to allow a representation and a use of the game at different scales: farmers, associations, institutions.

Box 20 WAG: Ideas and Objectives

Experiences of GEAU and ComMod: simulation tool to help water resource management
(role playing game + computational simulation models)

Aim at capitalising on this experience by designing a "reusable" game

"Upscaling Commod": UMR GEAU working group (2008-2009 - Ferrand, Farolfi, Abrami)
• Extend spatial and institutional scales of the ComMod process
> • Involve higher-level stakeholders
> • Open to larger groups
> • Use of abstract representations
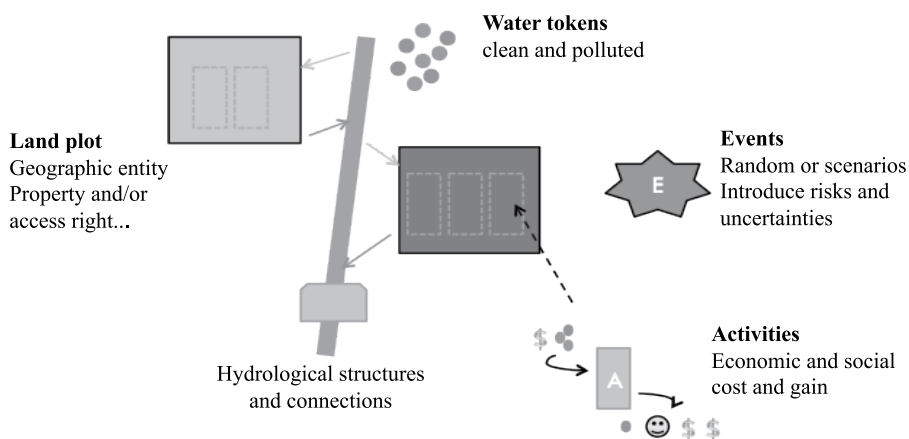> • Process that can be transferred to local partners

This game stems from the participative modelling approach *ComMod* – a method used by researchers at the *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD) who gathered together people from the same commune in which there were, for example, conflicts surrounding land use. This entailed having the different players participate in the building of their model so that they could become aware of the management issue dynamics of their environment – creating a game on paper or blackboard for example.

The aim is to be able to generalise this approach through the development of an expressive tool, so that it may be used in a great number of situations with bigger groups of participants: allowing local people to make the tool their own by building themselves their own catchment areas in order to discuss it together.

Diagram 33 WAG Principles

A set of flexible and adaptable bricks to design specific "playgrounds" (artificial drainage basins)

Water tokens
clean and polluted

Land plot
Geographic entity
Property and/or
access right...

Events
Random or scenarios
Introduce risks and
uncertainties

E

Activities
Economic and social
cost and gain

A

Hydrological structures
and connections

*Sources: https://sites.google.com/site/waghistory/wag-courses.*

There is a great deal of symbolical represen- tation work with numerous activities. The idea is to build an abstract base into which individuals can integrate their own modelling concepts concerning the catchment area in question.

Surrounding a stream or river for example, there will be geographical areas in which specific activities will be identified: agricultural zones, industries, etc. These activities are also the source of profits for their owners and are going to be more or less socially accepted.

The participants are going to play on the structure after having built it. This stage is important in obtaining a common structure of the catchment area. The principle being that according to different human activities, water will be drawn from the source of the catchment area and a certain quantity of more or less polluted water will be rejected.

Diagram 34 — Application Examples of WAG: Fogera Basin, Ethiopia
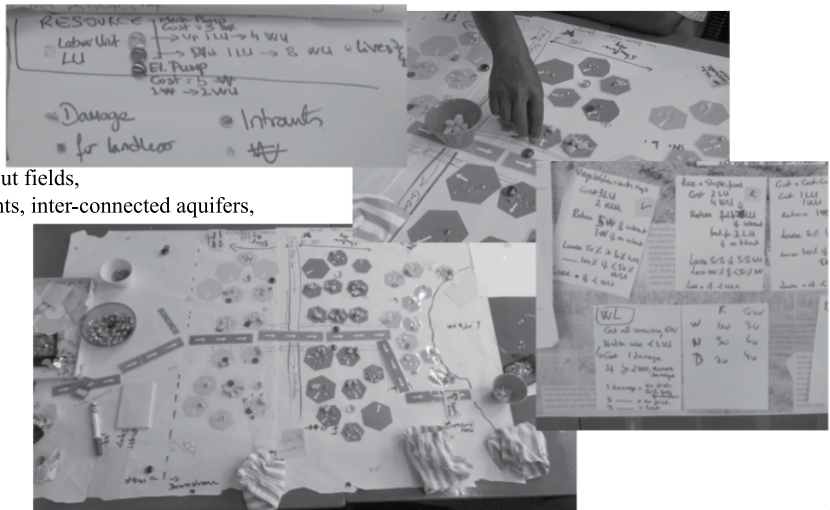
Farmers without fields,
work constraints, inter-connected aquifers,
humid area

Here is a catchment area created in Ethiopia. The streams and rivers and all activities can be recognised. Other than basic concepts, the problems faced are: lack of cultivable zones, presence of underground water. This example illustrates the possibility of including concepts to make the catchment area closer to reality.

Diagram 35 — Application Examples of WAG: Diga Basin, Ethiopia

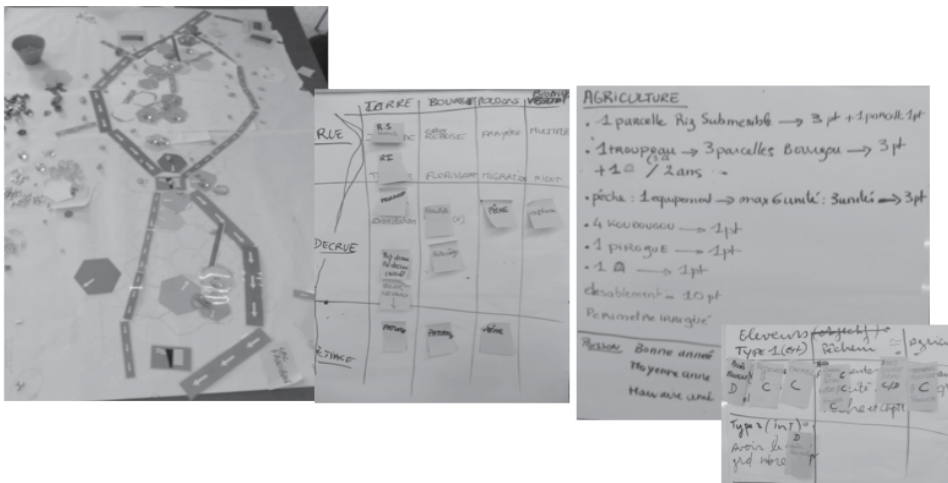Soil deterioration, termites,
deforestation
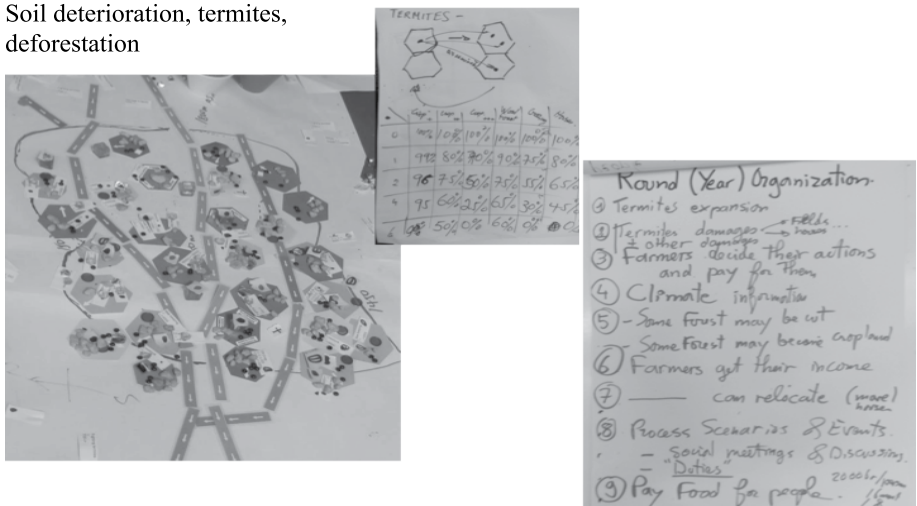
In order to take into account their local problems, the participants included in this example many supplementary stages linked to the propagation of termites, their development, etc.

Diagram 36 Application Examples of WAG: Niger Central Delta, Mali

❖ Multiple usages over time and space

Sources: https://sites.google.com/site/waghistory/wag-courses.

Here, the problems associated with the catchment area were linked to land use.

How is the water catchment area managed with WAT?

The manager(s) must manage the water catchment by taking multiple aspects into account: social dialogue (equity), environmental practices, economic data (viable policies).

Some people will represent farmers, others will be responsible for policies – concretely,

the catchment area manager may manage the dams according to the current and future situation he/she anticipates; he/she proposes or imposes management policies.

The manager may measure the water used, impose taxes, propose financial incentives, etc. To sum up the different informal measures, it is necessary to start a debate to advise the participants by proposing alternatives to crops that consume too much water, for example.

Phan Đinh Phước

I clearly remarked the brick diagram representing water quantity. In order to determine the quantity of water consumed by each of the activities in a water catchment area, you base yourselves upon statistical data, but on which information do you base yourselves for rejected water in order to measure the quantity of water and whether or not it is polluted?

[Benoit Gaudou]

To begin with, a quantity of water is placed at the catchment area's source and this quantity may vary. These models are made with the collaboration of field players who wish to study their catchment area, they have a good knowledge of the quantity and quality of the water used and rejected by different activities.

[Alexis Drogoul]

You are quite right to point out that data are not always available, especially when it's a question of pollution. One of the model's important parameters is the perception society has of an activity. Part of the decision in the models is based on perceptions rather than on real data.

We are developing an economic tool that will allow us provide an equitable technical management of the environment. How can we measure the quantity of water used by consumers and the quantity rejected? For households this is easy to calculate thanks to water meters, and as for rejected water we calculate it as 10% of consumed water. It is difficult to obtain reliable statistics for industry, as there are two supply sources: the supply company and direct drilling to consume underground supplies. It is

therefore impossible to obtain exact data for the quantity of water used and for the quantity and quality of water rejected.

[Alexis Drogoul]

Regarding this access problem and the reliability of data, I wish to specify that it is possible to diverge from these models and add a hidden water abstraction point for any interested group. An abstraction that does not exist and whose data we do not possess, but which is going to have an impact on general water resources. This is not difficult to integrate. We can take interest in activities that have both a hidden and a visible part in terms of abstraction and rejection of water. It is possible to estimate them and even calibrate them depending on our knowledge of groundwater.

Nguyễn Ngọc Minh

Is there any way of testing whether the model gives an accurate picture of reality?

[Benoit Gaudou]

The diagrams are very far from the real environment. The strength of these models is that it is the field players that represent the catchment area depending on their perceptions and according to the issues in question.

Võ Quốc Thanh

When you measure the density of branches of rivers and streams, do you use statistical data or a hydrodynamic model? It seems to me that WAT is more a water resources equilibrium model. Does this model evolve with time *versus* the rhythm of the seasons?

[Alexis Drogoul]

Hydrodynamic and statistical water flow models depend totally on the participants' perceptions. Technical knowledge and thus a precise hydrodynamic model may exist. It is also possible to obtain measurements about the flow of water according to time and periods of high and low water.

Before the training, we discussed with the JTD's organisers in order to decide whether we were going to use a real water catchment area with real data, identified players, etc., or depart from an abstract base. We have chosen the abstract base with the idea that you can more easily generalise what you have learned. Our objective is that you leave here with a vision that is above all methodological.

Box **21** **Steps to Build the Complete Model**

1. Building a hydrological network using agents (a): nodes
2. Building a hydrological network using agents (b): network
3. Addition of water on the network
4. Modelling the dynamics of water flow
5. Tracking the quantity and quality of water (a): definitions
6. Tracking the quantity and quality of water (b): user monitoring
7. Adding different sources to the network
8. Modelling of "human" activities
9. Modelling of the interactions between activities and the hydrological network
10. Modelling the owners of activities and a simple economical system
11. Addition of several activity types
12. Adding charts and output files
13. Differentiating the sources in the network
14. Calibration of the model
15. Modelling the basin administrator and its management actions
16. Addition of management actions to the activity owners

Sources: Authors' construction.

The presented stages correspond to sixteen different models. There is a progression in modelling and technical terms. Each of the models allows us to introduce GAMA functionalities. Each stage is an exercise: a particular objective is set, a certain number of functionalities that allow this objective to be represented are introduced, the model is then implemented allowing a verification of the understanding elements before we move on to another model. Our objective is for you to become autonomous when using this tool so that you will begin to raise questions concerning your future practices.

2.4.2. Practical Works And Methodological Input

The practical work took up the first three and a half days, from Monday morning to midday Thursday. Days 1 and 2 allowed for the implementation of the "scenery" of the model serving as a base for the training, that is to say the creation of a minimal water catchment area with a simplistic flow dynamic; this was the moment for the participants to get acquainted with GAMA and more generally with computer programming. Because of their varying profiles, many of the trainees had embarked upon this workshop with a certain apprehension concerning the "computer tool" in general, and this led the trainers to devote an entire afternoon (Day 2, Tuesday afternoon) to explanations in Vietnamese, so as not to add linguistic difficulties to computer ones. From Wednesday onwards, the modelling work became more interesting for most of the trainees, as the modelling of human

behaviours began to be addressed (those of the managers of activities within the catchment area, those of the area's administrator), which triggered numerous discussions about the best way to tackle this issue. This sequence finished at midday on Thursday when all the participants had succeeded in obtaining a same basic "neutral" model capable of being used for the study of more concrete questions closer to everyone's concerns – that is to say only describing certain dynamics considered to be "objective": the water cycle, pumping and rejection of water through activities, their economic cycle, their water needs, etc. The incremental construction of more and more complex and finalised models is one of the fundamental methodological inputs of agent-based modelling methods as it allows us, amongst other things, through the use of a same basic model enriched with "new" agents (economic, social, environmental, etc.), to evaluate and measure the impacts of these additions on the dynamics of the global system. From a didactic point of view, this was reflected during the workshop by a clear separation between the construction of the basic model – used to also introduce GAMA and its concepts – and a second, shorter part in which participants were encouraged to individually carry out their own additions to this model in response to a particular question. A list of questions that could be addressed with the help of such a model was thus submitted to the participants to choose from, whom were then asked to form four independent work groups, each working on one question within the framework of a specific scenario.

> Group 1 - scenario "home owners are confronted with a rise in sea level". The rise of sea water along the river is a potential source of activity disruption. Here it is necessary to model owners' behaviours in response to this disruption.

> Group 2 - scenario "the owners are free to not pay taxes, water police service is integrated". The catchment area manager's strategy is modelled to face this problem.

> Group 3 - scenario "additions of social behaviours for owners". The owners make decisions according to their activities but also according to other owners' behaviour. Defining in which order the different agents are going to act is an important aspect, at which moment the decisions are made will be defined.

> Group 4 - scenario "floods as a source of disruption". How the floods affect owners' activities is modelled. The question about owners' behaviour when faced with the risk of flooding is raised.

The trainees are divided into four groups with the support of a trainer. Practical work is constructed following two distinct stages: an analytical and reflective phase concerning the scenario with a first feedback discussed (synthetic approach by identifying how to integrate the data into the existing models; the computer is not used); after validation of each approach by the whole workshop there is a phase of technical implementation on the GAMA programme. A methodological briefing is proposed about these two stages of the work.

Group 1

Which modifications need to be made to this model?

First, we are going to add the characteristic "salt water" to the unit of clean and polluted water, and then we shall model the intrusion of salt water in the modelled hydrological network by using the sea as a starting point (see next diagram).

A new activity based on the growing of salt-resistant rice will be defined. Finally, the catchment area's administrator may encourage owners to adopt this strategy. The building of a dyke and drainage system is judged to be too costly and complex, so we opted for a pumping system in the fields to reduce salt levels. We shall simplify our approach by only taking into account the impact of salt water on agriculture.

The implementation stages in the model are:
- Adding of salt water in the nodes: the closer the hydrological network to the sea, the higher the salt levels;
- Our hypothesis is that salt content does not change from one node to another: from an initial value of 100, we estimate the closest node will be 95, then 90, etc.;
- Introduction of a new type of salt-resistant rice;
- Two scenarios appear depending on the salt water acceptability threshold: if the threshold is higher than one, farmers can continue traditional cropping by pumping salt-free water; if the level is beyond the threshold, another activity will be envisaged;

Diagram 37 Salt Water Intrusion

Salinity

decrease

SEE

Node
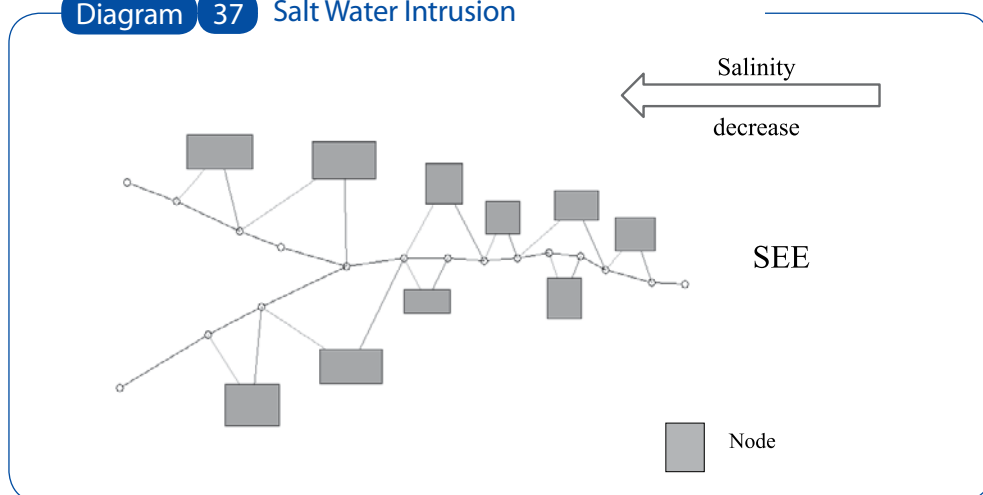
Sources: Trainees' construction.

- The catchment area's administrator may grant a bonus to owners who have modified their cropping systems.

Nguyễn Ngọc Minh

How do you intend to pump water to dilute salt levels? On which source are you basing yourselves?

Group 1

We have defined two technical means for fresh water: digging of wells for groundwater and adding chemical products to lower salt levels.

Nguyễn Tân Dan

Because of salt water intrusion, the groundwater will be contaminated; the introduction of chemical products comes at a cost. Have you integrated these two aspects? Finally, it seems important to me to remain in touch with reality: in the Mekong Delta, no variety of rice is salt-resistant.

[Arnaud Grignard]

Certain varieties of rice are being developed, even though we must evidently take into account the economic dimension. Another agent might be introduced: the pumping of salt water for prawn farms.

[Alexis Drogoul]

Your two positions illustrate in a certain way the debates that have been going on since 1960 in computer modelling: is it necessary to be as realistic as possible or can we simplify reality to the benefit of induction and reflection? Everyone would like to have realist models, but we must remain aware that the computer tool has its limits; the answers supplied by the platform lead us into an abstract world.

Group 2

Diagram 38 — Owner's Freedom To Not Pay Taxes (1)

NOT POLLUTE

POLLUTE BUT DO NOT WANT TO PAY

OWNERS PAY THE POLLUTED TAXES

ATTITUDE OF OWNERS

Limited pollution

ADMINISTRATORS' POLICIES

OWNERS DO NOT PAY THE POLLUTED TAXES

Owners' reactions Scenario with Administrators' Policies

Pay taxes

Change the type of business activities

WATER POLICE

Account >= tax cost (a year)

Close the business

1. Confirm technical polluted index

2. Random polluted levels

3. Pay for each polluted level (level 1,2,3,…)

4. Use remedial ways for the behaviours that do not pay the tax

Sources: Trainees' construction.

Diagram 39 — Owner's Freedom To Not Pay Taxes (2)

Administrators

RAISE TAXES

Expected income tax

REAL TAXES

• Number of polluters
• Polluter tax

CREATE

Dysfunctioning activity

Willing to pay

Police

Change activity type

ASK

ACTIVITIES OF OWNERS

NOT PAY

ASK

POLLUTED

NOT POLLUTED

PAY
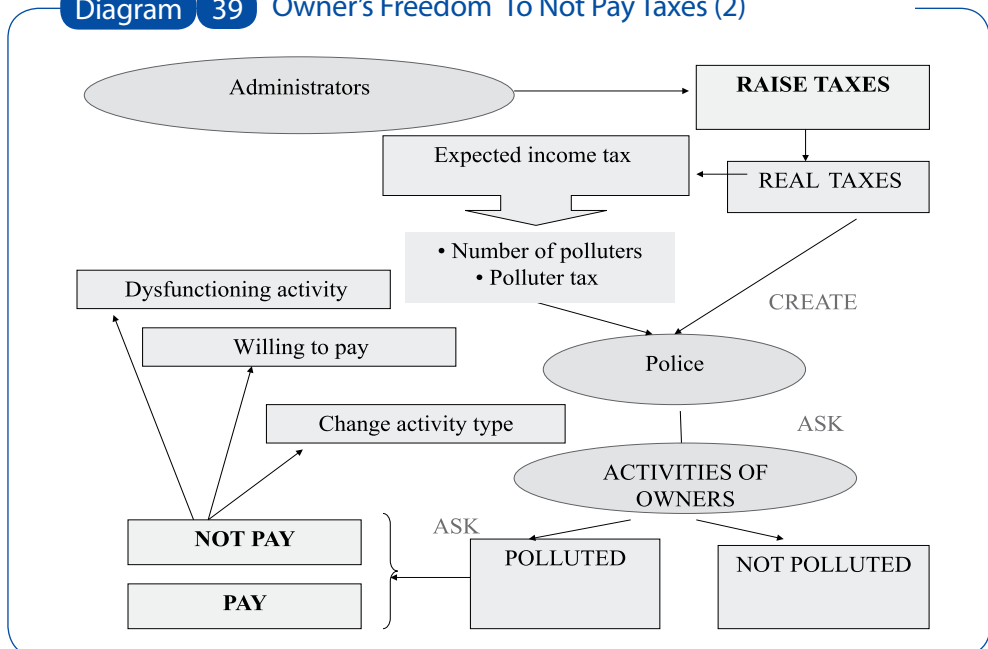
Sources: Trainees' construction.

Our module is a support tool for the decision-making of the catchment area's manager. The model is based upon owners' attitudes.

Which policies does the administrator implement? What are the attributes of the water police?

Firstly, we identify pollution levels and different levels of tax to be paid depending on pollution caused by activities. Next, it is necessary to define measures in the case where the payment of this tax is refused.

Each owner must have a bank account containing an amount of money higher than the tax to be paid.

[Patrick Taillandier]

Do all the owners behave in the same way, particularly regarding the tax payment? Which factors determine whether they pay the tax or not?

Group 2

The criterion determining the payment or non-payment of the tax is the pollution level. The higher the level of pollution, the less the activity owners will be inclined to pay the tax.

[Alexis Drogoul]

Do you envisage simplifying the model? Do you wish to represent everything in the administrator's behaviour?

Group 2

The diagram presented gives us a glimpse of the problematic; it will be simplified when implemented.

[Alexis Drogoul]

A lot of things are not specified and are going to be difficult to model unless we opt for simplistic hypotheses. At the same time, you appear to have a clear idea of what you are doing. I think this models fits well with what has been discussed during the week.

Diagram 40 Give to Owners a Social Behaviour (Observation and Imitation of Neighbours)

The Neighbours

Sources: Trainees' construction.

Group 3

What happens if the activity is in a state of disruption?

When faced with a disrupted situation, the owner observes his neighbours actions before making a decision. Two types of neighbourhood are considered: upstream and downstream.

Why is the activity disrupted?

Four types of information are examined: Has the owner paid his taxes? Does he receive help from the administrator? Has he got enough water for his activities? What is the nature of these activities?

The following questions are asked about the neighbourhood: What is the nature of the activities? Are the activities disrupted? If so, the envisaged scenarios are: the activity is repaired; the activity is modified – is the activity then more lucrative?

In order to make the decision to repair or change an activity, the owner bases his decision on his neighbours' situations and chooses from the three following criteria:
- Comparison of income generated by activity;
- Pollution from the activity;
- Financial capacity in case of change in activity.

Dương Hông Huê

Which agents will be created or modified in order to attain these objectives?

Group 3

We worked on the technical stages for the implementation of GAMA. We are not going to introduce new information. On the other hand, new agents are going to be defined: Who are the neighbours? What needs to be implemented by the owners?

Group 4

Our questions concern three distinct points: How can we define the impact of flooding? What measures can be taken to combat flooding? Who is financing these measures? We have defined two rates of income loss – 50% and 100%. Upstream activities suffer more damage than downstream ones. The rates of income loss for each activity owner are determined according to water flow.

The choice of adaptation measures depends on the type of activity: for industries that are difficult to relocate, dykes are built; agricultural activities may also be modified – a change to aquaculture for example.

Methodological Briefing (1)

[Alexis Drogoul]

These presentations are extremely interesting because they are situated between two worlds: the real one and that of modelling. Many constraints from the real world have been proposed even though they were not included in the suggested scenarios – for example, the cost of the building of a dyke or the relocation of a factory.

Your hypotheses identify four very different ways of approaching modelling. This is explained by the diversity of the proposed

scenarios and the profiles of the group members. I have classified the four groups:

- Group 1 has adopted a very operational approach. It is a presentation of modelling that is specific to GAMA and respects the constraints of the tool. The implementation is almost complete: we are in the tool; the model's hypotheses are so far from reality that they give rise to debate;
- Group 2 has adopted an essentially descriptive method. Hypotheses that must have been there are reflected but are not presented. Theirs is a rather normative description of the system's functioning that does not necessarily connect up with the operational constraints of the simulator;
- The presentation of Group 3 is hypothetical and hinges on questions. The link with the model's implementation is outlined. What is brought to the fore is the questioning without necessarily bringing any answers. The method consists more in asking questions about what one wishes to model than in defining technical solutions that may be implemented in the programme;
- Group 4's method corresponds to a modellers' one. There is a description of the model that is not that of the real system, which is based on the preceding model without making any specific reference to GAMA. It is an essentially conceptual model that might have been produced in any other computer tool.

Groups 2 and 3 base their model on a hypothetical method by bringing reality into question; the two other groups slipped into the world of the model.

From these four groups, we are lucky to have four different ways of conceiving modelling for a scientific approach that fluctuates between the constraints of reality and those of the computer tool.

I have no worries about your modelling abilities, as the groups which have gone the furthest in the implementation are raising questions about the relationship with reality, whereas the groups nearest to reality have better elaborated hypotheses and will thus have less difficulty implementing them.

Day 5, Friday 20th July

Implementation work of groups in GAMA

Methodological Briefing (2)

[Alexis Drogoul]

- Yesterday, Group 1 gave a very operational presentation linked to GAMA. While remaining operational, the presentation was more descriptive, making particular use of realist data from the geographical information file;
- Group 2 was very descriptive, almost normative. The presentation highlighted the functioning of the system with numerous command lines. The diagram used to represent the conceptual solution at the outset served as a support to subsequently explain the model's functioning.

These two groups started from two distinct points, but have arrived at a discourse that describes the model and shows how it was implemented in GAMA.

- The presentation of Group 3 was based on questioning that was very near to reality but far from the model. Today, the questions

have been deleted, hypotheses have been made, and lines of code describe the world using relatively advanced techniques compared to what we learned this week. The group moved from the real to the virtual world;

- The presentation of Group 4 was above all conceptual in the modelling domain but without references to any implementation. Like the other groups, they finished with a descriptive presentation. The extension is twofold: operational and realist, as only this group referred to the realities specific to the Mekong and to the behaviour of the delta's inhabitants.

Finally, in a very short time, we have here four comparable discourses in terms of representation and abstraction relating to the world and implementation. You all converged and the models are described as small, closed worlds.

There are some references to the real world, but the discourse essentially concerns the model; it is a matter of agents, environment and interactions. In spite of the virtual dimension, you have a discourse of realist interpretation, projecting on to the models' properties of the real world – *versus* the realism of measures to fight against salt, mechanisms of police control, etc. The objectives of this exercise have been assimilated: the model is used as an element on which a description or representation of what we should like to see in the world is based.

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