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Linking a farming system modelling tool (Olympe) with a multi-agent-system software (Cormas) in order to understand resources uses in agricultural complex systems.

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Linking a farming system modelling tool (Olympe) with a multi-agent-system software (Cormas) in order to understand resources uses in agricultural complex systems.

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Introduction

Models are never objective as different ones can be used to describe about the same phenomena, seen under different angles. It can be interesting to combine different types of models representing different actors or representative of different scales to understanding a whole phenomenon. For that purpose we studied the interests of combining two kinds of representation of agricultural resources exploitation : a « systemic representation of farming systems» and a « multi-agent modelling of resource management ».

The goal of this paper is to propose an articulation between a farming system modelling software "Olympe" and an agent-based simulation platform "Cormas". Olympe (developed by an INRA/CIRAD/IAMM collaboration), is used to characterize and analyse farming systems identified as major centers of decision in agriculture. Cormas (developed by CIRAD) allows the representation of complex situations taking into account interactions between various actors.

We will first describe both models and display the interest of combining the tools. Then, we will see how we developed a new platform based on both of the software. Thirdly, we will present our platform through a simple pedagogic example. Lastly, we will discus pros and cons of such approach and identify perspectives.

I. The objective of the study

1.1 Farming systems modelling

a. Introduction to the model, origin and working principe

Frequently used by agro-economists, this model is based on a systemic representation of farming systems. It represents farming activities as a set of specific and clearly characterized cropping and livestock systems *(figure 1)*. For each techno-economical scale a different system is defined, in which sub-systems will evolve. This model defines a certain number of notions which will be used to study farming on a technical and economical point of view.

This model is used as a decision making process and communication support tool. It provides a synthetic economic vision of farming complexity. Each kind of system is precisely defined according to the "general system" of J.L. Le Moigne (1990), by a function, an environment, transformations it generates and its finality. P. Jouve (1992), following R Badouin (1985) provides a general framework for farming systems diagnosis[1] and analysis. Indeed, each kind of system has a specific role for production, conservation or other activities that has to be integrated in the whole farm organization.

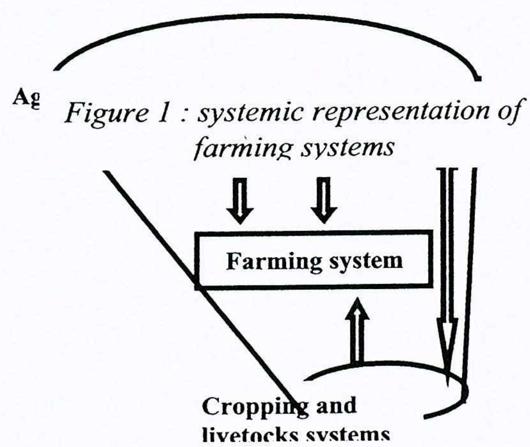

Figure 1 : systemic representation of farming systems

[1] *Diagnostic seen as :* "Judgment given in a short time on a situation or a state, in order to guide action

b. The software "Olympe" and its uses

The software Olympe focus on one particular actor : the farmer and its holding system that managed factors of production (land, labour and capital as well as information) through activities regrouped in cropping and livestock systems *(figure 2)*. It is used as a decision support tool by various potential actors: farmers in order to manage their holding, by developers in order to understand impact of agricultural policies and by researchers to understand farmers' strategies and trajectories. Olympe can also be used for regional analysis with groups of farmers in order to measure flows (of inputs/outputs as well as capital and externalities). Primary data are obtained through classical farming systems surveys. Every "entity" is pre-defined in the software and the user has only to change parameters and enter data to build his own model. There is no internal regulations or particular rules generated by the software with conditionalities.

Indeed, the various types of systems are chosen to be significant of the state of the farm. It allows the study of characteristic values relevant at different scales in a perspective of farming management. The farmer is the main decision centre. Technical innovation consists in modifying cultural practices (and associated costs and benefits) or replacing a cropping/livestock system by another one. Thus, The understanding of farmers' strategies required to link the main calculated economic characteristics (investments, cash flow, funding capacity …) with the combination of cropping/livestok systems as well as other sources of income, hunting, fishing, handicraft and non-agricultural activities: a diversity that characterize many farmers.

This story of the farming system composition is called the path.

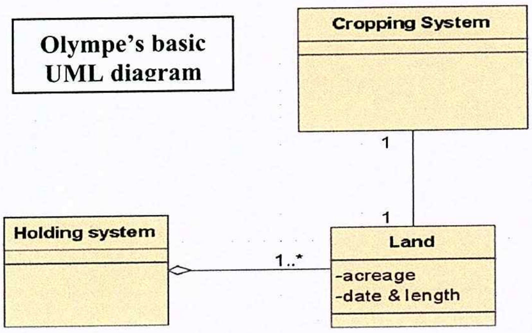

Figure 2: simplified Olympe class diagram

1.2 Multi-agent modelling of resources management : a way to deal with complex systems.

a. Model framework, origin and working principe

Multi agent modelling represents complex systems as a set of individual actors whose will interact in a particular environment to make the global system emerge (Ferber J., 1995),. Each "agent" will take his own decisions from his goal and the representation he has of the environment *(figure 3)*. This kind of modelling might be adapted to represent social organisation and that is why it is now a day used by the Cirad to represent resources management problems in a participative modelling approach.

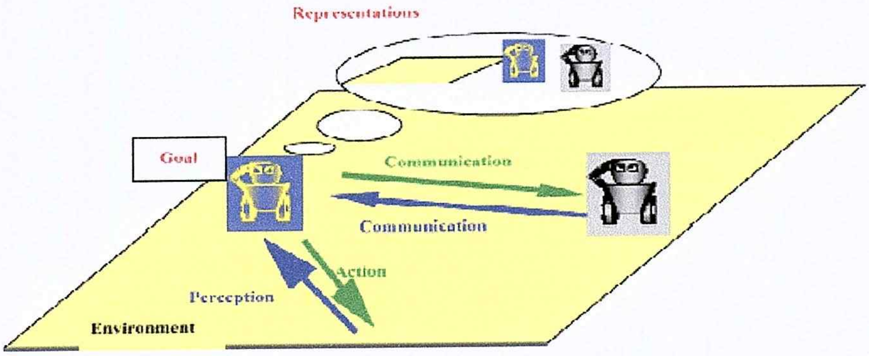

Figure 3: multi-agent system represented by Ferber

By using such a representation, it is possible to study what consequences will have a change of any definition in the system. Can it be rules of cooperation, perception an agent has on the environment, or a different quantity of resources.

b. *Cormas' model and its utilisation*

From the agent-based simulation platform Cormas which is based a companion-modelling approach. It is a computer tool which uses object programming to define each entity of the model as an instance of a "class" defined by the modeller. In fact, basic classes ("An agent" who is the active entity, "a spatial entity" which is the elementary part of the topologic back-up, and "a passive entity") are pre-defined with basic characteristics and functions and the user will create his own classes from those to build his own model. He can for example define a "farmer" as a "located agent" who he will link with an object "farm" which he would have define before *(figure 4)*. Then it will be possible to study what influence will have specific definitions on the evolution.

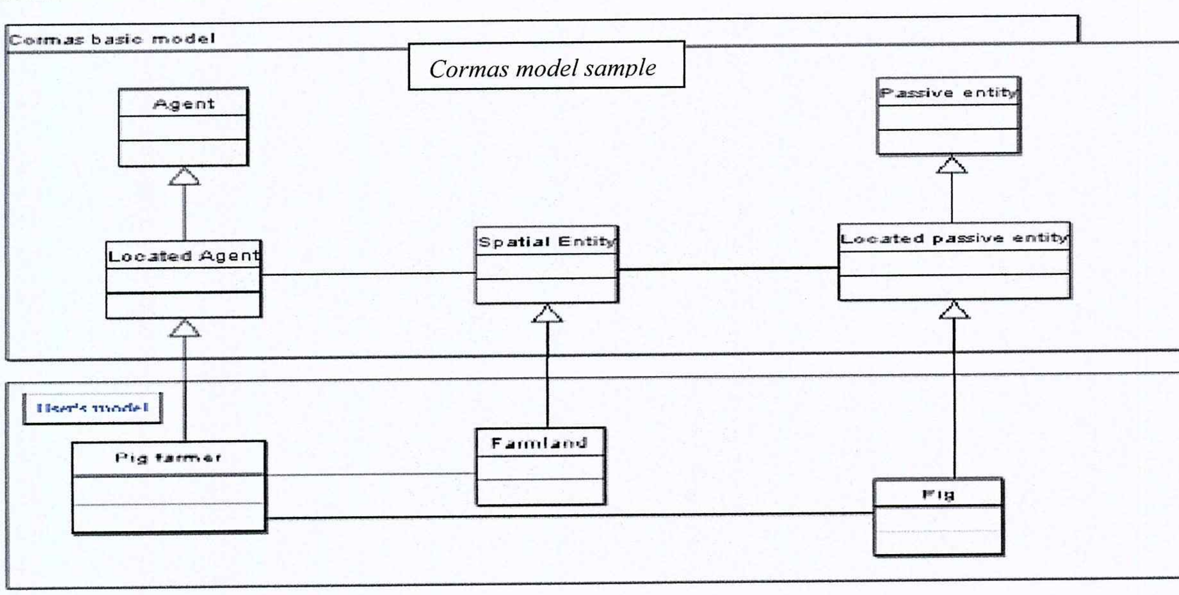

Figure 4: Class diagram of a cormas model sample

1.3 Complementarities of both approaches

The interest of combining both approaches is to represent, simulate and understand the roles of the different actors and their strategies and, reciprocally, to see what influence the farmers' strategies will have on the system according to the initial situation and definitions of the rest of the system.

To represent that kind of phenomenon, what's more natural than using a suited representation of interaction situations, multi-agent modelling, and to give to the agent of this model a systemic representation of their holding *(figure 5)*, in order to base ourselves on this usual representation to define their individual strategies.

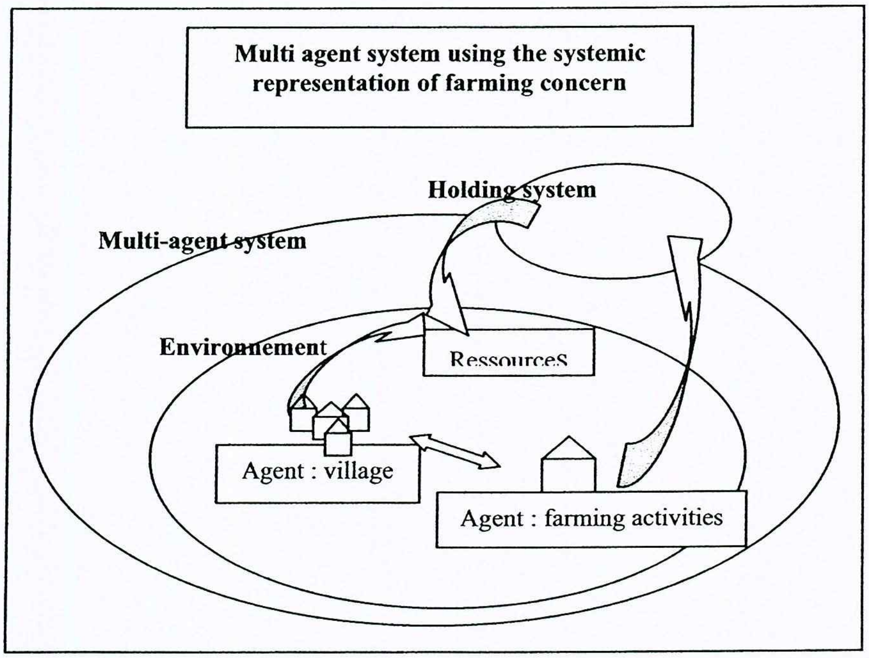

Figure 5: Models' coupling

One major interest in this work is to bring different actors together on a same model, in the same restrictive world in order to analyse interactions. Agents based models are often used to represent and analyse socials problems at a regional scale, on a limited resource and impacts on that resource such as water, land, and pollution management or forest depletion for example. In agriculture, using a systemic representation, at a relatively well defined unit, with a relatively easily "handable" economic assessment allow to look into decision making process in details with accuracy. The prospective analysis with Olympe provides scenarios that enable to explore potentialities in partnership with farmers or any other actors involved in agriculture. Thus, accumulated knowledge on several years enable to validate hypothesis and coherence with reality. But Olympe is mono-actor with no interactions between actors. It does not permit consequently interactions analysis, in particular with other actors. Linking Olympe wit a MAS platform has therefore two objectives : to have a far better definition of the object "farmer" in the SMA (using Olympe data base for economic information on farmers' behaviours) while SMA allow actors' interactions analysis, between farmers first and last between farmers and other actors (Government, traders, policy makers, developers, project managers ....). In other words, Olympe feed the SMA for one particular, but crucial, actor : the farmer.

II. Methodology to link the two softwares.

2.1 Objectives and technical choices

After having defined the actors involved (ie the level of analysis, local/farming systems and regional/MAS) and the philosophy behind the approach and uses of the two softwares, we can now deduce the main functions we would like to integrate in order to assure an effective and useful link. The objective is to assure a correct data transfer (with the relevant data), from Olympe to Cormas to calibrate farms and activities related to agriculture with either primary data collected in original surveys, or "typical values" representative of "standart" farming systems. Olympe is indeed an efficient tool to economically characterize a large variety of farms from the smallest to the large estates with various degree of precision; according to the primary objective of users. The number of Olympe users is growing and therefore feed a very interesting and pragmatic "network of users" sharing their data set and experience, leading to a potentially formidable data base of farming systems in the world. The main advantage is that comparisons are possible due to the fat that users share the same tools the same simple but efficient economic indicators and therefore have in common the same language and definitions set. Such date can be used to calibrate a multi-agent model. Last, it could be interesting to create a feedback link of the data once used in Cormas back to Olympe to provide to Olympe users the possibility of reaction. Such a dynamic link would be very useful but requires a compatibility between the two softwares (written in different languages) which seems to be difficult to implement.

The objective has been so far to create a modelling framework, with data from Olympe feeding the actor "farmer" in Cormas, which would allow users to include all management indicators of farming systems under Olympe into a multi-agent model through the definition of a proper Olympe data import protocole in the multi-agent model.

We have choose to use only the Cormas platform during the simulations. Specific classes are defined to respect Olympe's representation of farming systems and to accept data originally formatted in Olympe. An XML file, with the required structure, is generated by Olympe as an output and loaded by Cormas at the beginning of the simulation. In other words, Olympe conceptual model is introduced in Cormas' world...

2.2 Olympe's conceptual model in Cormas' world

We need to expose more technical details in the linkage in order to understand issues and the consequent limits of this work. Olympe will be used here only to model and not to simulate. Data are generated from Olympe for the actor "farmer" when Cormas generates the other actors in his own format. The simulation is implemented under Cormas. The data obtained and transfered with Olympe arethe following:

- Products quantity (inputs/outputs) and costs/benefits
- Cropping and livestock systems structure with 4 different format for crops: annual crops, multi-annual crop (from 1 to 5 years), perennial crops (more than 5 years) and "animals" (indeed a very potentially complex livestock management tool to characterise all types of livestock systems). A cropping system is defined by the economic component of the

"technical pathway" (which is not technically well precised) including lifespan, costs/benefits and labour requirements.

- Global farming system characteristic (structural costs, financial costs and all sorts of other benefits and expenses).

Such conceptual organisation is described on Olympe UML classes diagram *(figure 6)*.

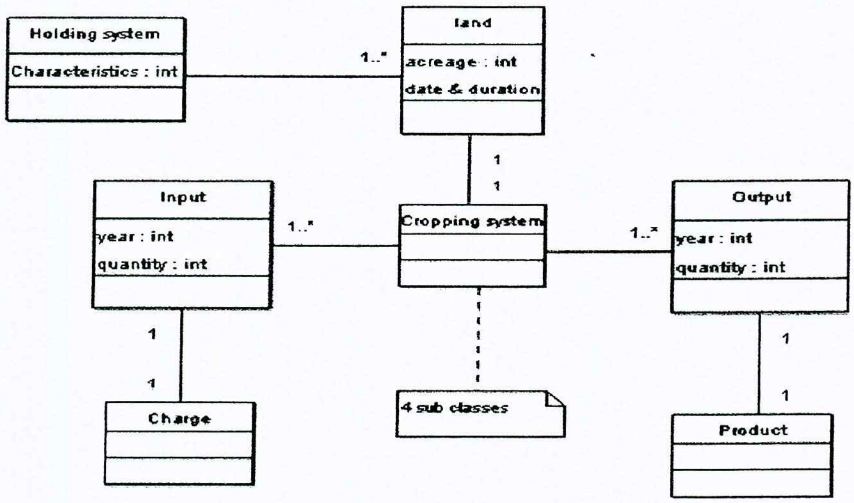

Figure 6: Olympe class diagram

It is important to mention that in such a framework, Olympe will only provide the economical results of each sub-systems as well as at the farm level

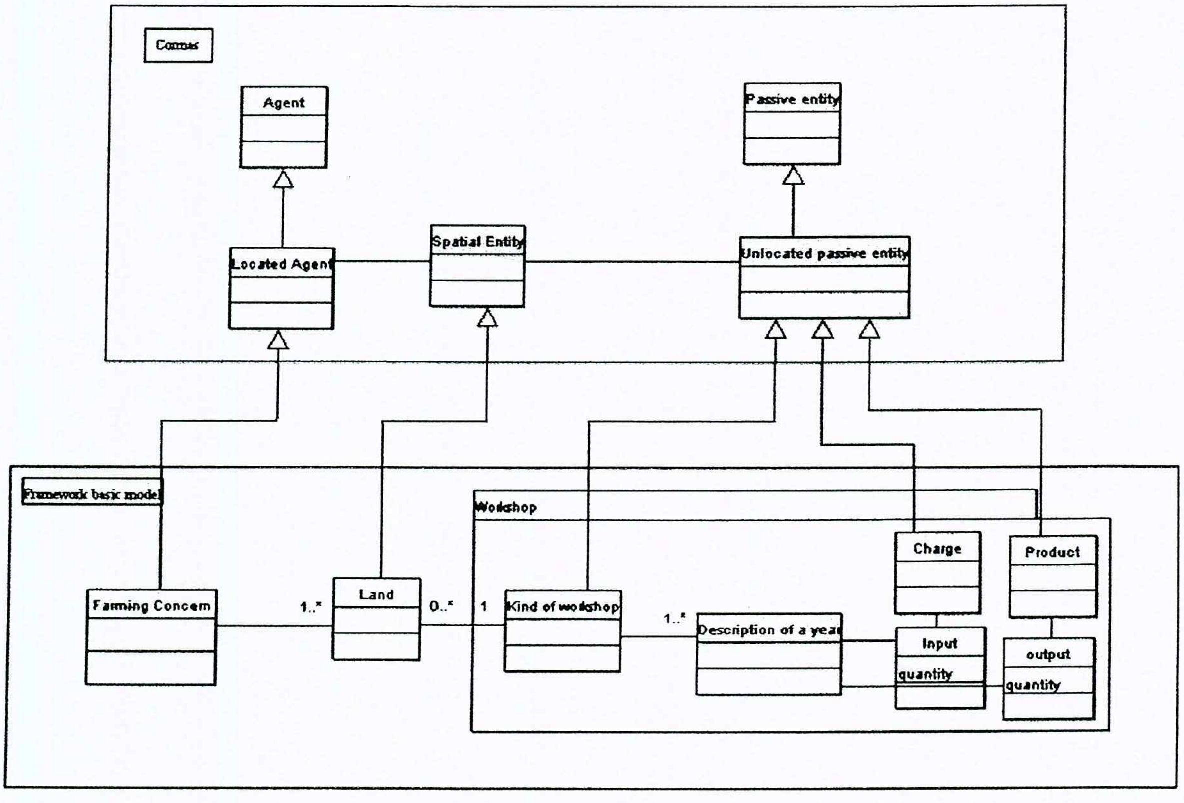

Figure 7: Class diagram of our platform

As the centre of decision in the systemic representation is defined at the smallholding level, we choose to identify the actor "farmer" and his family (livelihood) with the Farming system which would be a sub-class of "Located agent" in MSA. The farmer owns some land which is cropped according to a "Kind of activities" class. "Land" is a sub-class of spatial entity and "Kind of activities" a sub-class of passive entity (see *figure 7)*. Costs, productions and benefits are defined with Olympe before beginning the simulation (under Cormas) and are never modified after introduction in Cormas ; in other words , this is so far a one way process. Agents (actors) can only change in the list of activities ("kind of activities") according to whatever available parameter the use wants.

III Example of a simulation carried out by our platform

3.1 Description or the example

This example has been developed for a pedagogic purpose in order to show the potential of such combination and a method to implement it rather than for building a real case-sudy. MAS will be used to represent interactions between farmers, with a behaviour defined according to Olympe economic situation. The interest lies in the definition of the possible interactions and the influence on the simulation results.on individual strategies.

The example is based on a real situation observed in Indonesia, in the province of West Kalimantan (Borneo) where rubber farmers diversify with oil palm and other activities as well as integrating new cropping methods an improved agroforestry practices (Leconte J., 2000). Such situation is quite typical of that of post-pioneer areas where diversification is a risks limitation strategy after a period of monoculture when farmers, in the first phase of pioneer zones, rely only on one crop, in that case the jungle rubber system (an extensive agroforestry rubber based system), (Penot E., 2001). Such example can be later on developed for typical pioneer areas (Amazonia, Cambodia , West FAricaetc ...) Farming system characterisation as well as monitoring between 1997 and 2002 have been done with emphasis on farmers' strategies identification. In our example, interactions correspond to knowledge transfer, and individual strategies is limited to the choice of crops rotation.

Different sorts of "knowledge transfer": Two types of transferred have been selected for the purpose of this example :

- "Theoretical learning": farmers knows how to apply technology recommendations or adapted recommendations two years after having been in contact with the new system through their relatives. Once a farmer has acquired the know-how, he begins to teach it to his relatives.
- "Observation as learning process": a farmer acquire the know-how once one of his relatives has established the new cropping system on his own farm.

Different individual strategies:

- The "cautionous strategy": a farmer establish a new cropping system only if he can afford to fund the plantation and cover the establishment costs.

- The “innovative strategy”: a farmer systemically establishes a new cropping system, as soon as he thinks that it can be more profitable than other crops, in particular annual crops, even if credit ids required. In other words, he‘s taking at least some financial risks.

Different situations have been simulated. Each farmer can choose according to his capacity a level of investment in a new cropping system according to his financial situation well defined through Olympe. The multi-agent modelling allows to define the transfer of knowledge, its evolution, and the geographical aspect of the problem (diffusion), trough a simulated map.

Depending on various initial situations, interactions rules and consequent farmers’ strategies can influence the simulation and its results. The purpose of this example is only to illustrate that both representation of the farmer as an actor in Olympe and in a MAS can be combined and useful to study farmers under different angles, and how it is possible to build simulation leading to scenarios. This example is not supposed to be representative as data and rules have neither been calibrated nor tested according to the sensibility of initial parameters.

3.2 Description of an outstanding simulation

We simulated a situation in which we gather “observation as a learning process ” and “Cautionaous strategy”. In that simulation, there only are 3 different cropping systems: i) “upland rice crop”, which is not very profitable but provide food security ; ii) “Jungle Rubber” (classical extensive rubber agroforestry system) which is more profitable but only 15 years after having been installed (long immature period); and iii) RAS (improved Rubber Agroforestry Systems, developed by the SRAP project in partnership with farmers through on-farm experimentation), which are highly profitable with upland rice intercropping for the first years but require capital for implementation .

Initialisation of the simulation

20 farming systems are generated and placed on the topological support. Among those 20 farms, 4 are chosen as having the know-how to install the new rubber cropping system (RAS). Others can only grow the classical upland rice crop and Jungle Rubber. Each received initial funds and a random set of both cropping systems installed on 9 plots. In that example, jungle rubber crops are matures at the beginning of the simulation. Each farm is linked to two others (nearest smallholding not too far on the map) who are considered as “relatives”.

Description of each step during the simulation

Each farmer will develop the following activities:

- Cropping its plots according to the chosen cropping systems.
- The choose of the best cropping system he can afford according to his financial availability and its productivity.
- learn how to install the new cropping system if one of his relatives has already installed it.

Observations

The following picture is a simulated map of the situation at a key point of the simulation *(figure 8)*. Details about that particular simulation are presented in the framework 1.

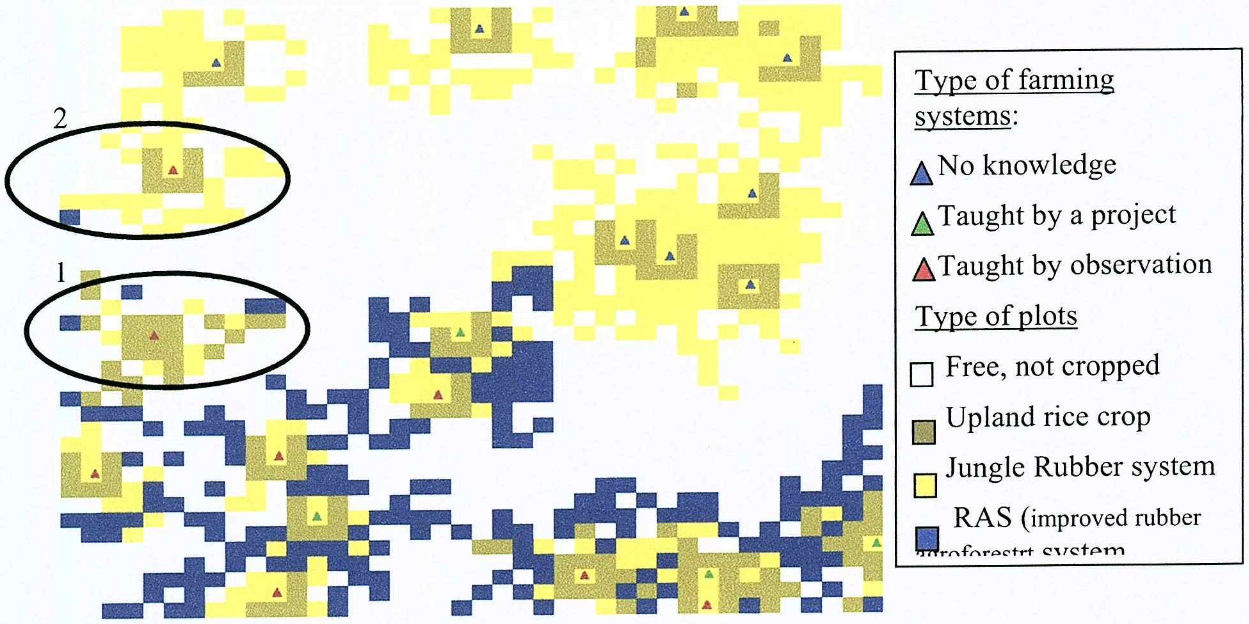

Figure 8: situation after 27 years of simulation

Framework 1 : details of the simulation

This map 8 displays the situation at the 27th step of the simulation. We can notice than after about 30 years of simulation, farmers that have developed RAS are all located in the southern part of the map, due to the fact that the 4 smallholdings with preliminary knowledge at the beginning of the simulation are all in that area and that the transfer of knowledge is linked to geographical proximity.

At the very beginning of the simulation, almost every farmer from the south had indeed implemented the new cropping system. However, the farmers circled by the circle n° 1 on the map, had only upland rice crops at the initialisation. He then began to plant "Jungle rubber" systems at the beginning of the simulation but he soon lacks funds to invest in other cropping systems. So when he learns how to implement RAS, he can't afford it and has to wait for "jungle rubber" to be productive.

Due to their geographical placement, farmers from the north have all a link as relatives except the farmer n° 2. Farmer n°2 must wait for farmer n° 1 to establish his first RAS to learn how to install it. It had to wait 30 years in that simulation. And then only, northern farmers can have access to the information.

We can notice that if we had chosen the "innovative strategy", farmer n° 1 would have planted RAS as soon as he would have learned and the all the northern area would have have access to information much earlier. On a same way, a "theoretical learning" would have allowed the northern area to install RAS before farmer n° 1.

The figure 9 shows the situation after 56 years.

Of course, this example is very simple but show how Olympe data can be used to feed the "farmer actor " in a MAS.

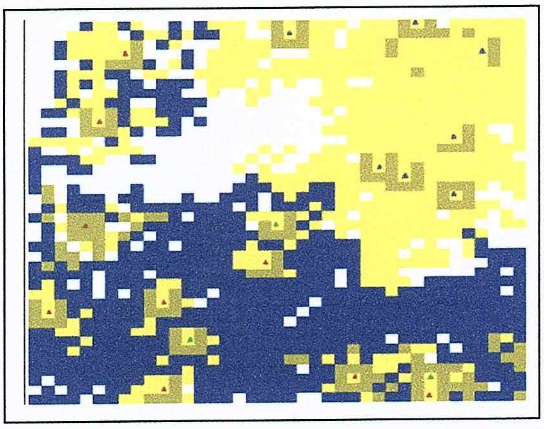

Figure 9 : Situation after 56 years

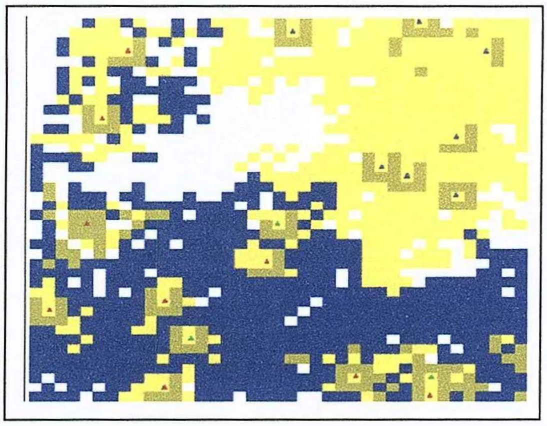

Figure 9 : Situation after 56 years

Limits and perspectives

3.3 Studies of Sensibility

An important point about the simulations done with this platform (CORMAS) is that there are a lot of parameters due to the precision of the information concerning the cropping systems generated by Olympe. It seems there fore necessary to verify the stability of the model and the validity of the values obtained by the MAS.

3.4 Multidisciplinary studies

According to the data structure used by such a platform, the data transfer between Cormas to Olympe (feedback) is possible but it has not yet been implemented due to lack of time. Such a link would allow to look at any farming systems at any time of the simulation and to verify if agent choices are rational. Decision farmers rules can be defined very precisely as economic information provided by Olympe can be very accurate and precise. But validation should be carefully implemented as complexity grows with linkages to other actors.

4 Conclusion

The objective of the study was to couple accurate economic information from a farming system modelling tool, Olympe , into a MAS in order to obtain a better definition of the actor "farmer" as well as to profit from potential data base created with olympe on various types of farming systems. However the two sofwares have been written in a different languages with different format. A linkage has been effectively developed in a pedagogic perspective in order to show the interest of coupling the two tools in order to better explain complex systems and impact of technical changes in situations where the farmer is a very major actor and has to be economically defined with precision. MSA allows interactions analysis that is not possible with Olympe. The two softwares appear very complementary beside their different objectives.

Such initial work paves the way for further work in coupling both tools with all the level of complexity required by some agrarians situations.

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