COUPLING THE FARMING SYSTEM MODELLING TOOL ‘OLYMPE’ WITH THE MULTI-AGENT-SYSTEM SOFTWARE SYSTEM ‘CORMAS’ TO UNDERSTAND THE USE OF RESOURCES IN COMPLEX AGRICULTURAL SYSTEMS

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Abstract

This paper describes how the farming system modelling software ‘Olympe’ (developed in collaboration by INRA/CIRAD/IAMM) can be coupled with the agent-based simulation platform ‘Cormas’ to better characterize and analyse farming systems identified as major centres of decision in agriculture. Cormas (developed by CIRAD) enables representation of complex situations and takes into account interactions between different stakeholders. First we describe the two models and the potential benefits of combining the tools, then we describe how we developed a new platform based on the two software systems, and finally we illustrate how the new platform can be used with a simple example developed for educational purposes. The advantages and limits of this type of approach are discussed along with possible further developments.

INTRODUCTION

Models can never be completely objective since different models can be used to describe the same phenomena from a different point of view. However it is sometimes useful to combine different types of models representing different stakeholders or different scales to better understand a phenomenon as a whole. To this end, we evaluated the advantages of combining two kinds of representation of the exploitation of agricultural resources: a « systemic representation of farming systems » and a « multi-agent model of resource management ».

The goal of this paper is to propose coupling the farming system modelling system ‘Olympe’ and the agent-based simulation platform ‘Cormas’. Olympe (developed in collaboration by INRA/CIRAD/IAMM) to characterize and analyse farming systems identified as major centres of decision in agriculture. Cormas (developed by CIRAD) enables representation of complex situations taking into account interactions between various stakeholders.

The objective of the study was to couple accurate economic information from the farming system modelling tool Olympe with a MAS to obtain a better definition of the ‘farmer’ agent as well as to profit from a potential data base created under Olympe which includes information on various types of farming systems. However the two software systems are written in different languages using different formats. A link was created for educational purposes to show the advantages of coupling the two tools, i.e. to better explain complex systems and the impact of technical changes in situations where the farmer is one of the major stakeholders and whose needs consequently have to be analysed from an economic perspective. MSA allows analysis of interactions and this is not possible with Olympe. The aims of the two software systems may be different, but in fact they are complementary.

This initial study paves the way for further work in coupling both tools at the different levels of complexity required for the analysis of different agrarian situations.

We first describe the two models and highlight the benefits of combining the tools. We then describe how we developed the new joint platform, which we present using a simple educational example. Finally, we discuss the advantages and limits of such an approach and identify possible future developments.

THE OBJECTIVE OF THE STUDY

Farming Systems Modelling

The model, its origin and its working principle

This model is frequently used by agro-economists and is based on the systemic representation of farming systems. It represents farming activities as a set of specific and clearly characterized systems *(figure 1)*. For each techno-economic scale, a different system is defined in which sub-systems evolve. The model

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defines a certain number of notions which are used to study farming systems from a technical and economic point of view.

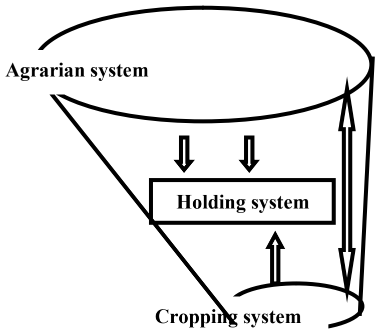

Figure 1: systemic representation of farming systems

This model is used as a tool to support decision making processes and communication and provides an economic synopsis of the complexity of farming systems. Each kind of system is defined on the basis of the 'general system' proposed by J.L. Le Moigne (Le Moigne 1990), by its function, its context, the transformations it generates and its finality. P. Jouve (1992), following R. Badouin (1985), provided a general framework for the diagnosis and analysis of farming systems. Indeed, each kind of system plays a specific role in production, conservation or in other activities which have to be integrated in the organization of the whole farm.

The 'Olympe' software system and its uses

Olympe software focuses on one particular stakeholder: the farmer and on his holding system which manages production factors (land, labour and capital as well as information) through activities grouped in cropping and livestock systems *(figure 2)*. It can be used as a decision support tool by a range of different stakeholders: by farmers to manage their holding, by developers to understand the impact of agricultural policies, and by researchers to understand farmers' strategies and pathways. Olympe can also be used by groups of farmers for regional analysis to measure flows (of inputs/outputs as well as capital and externalities). Primary data are obtained through classical surveys of farming systems. Each 'entity' is pre-defined in the software and the user needs only change parameters and enter data to build his own model. There are no internal regulations or particular rules generated by the software with conditionality.

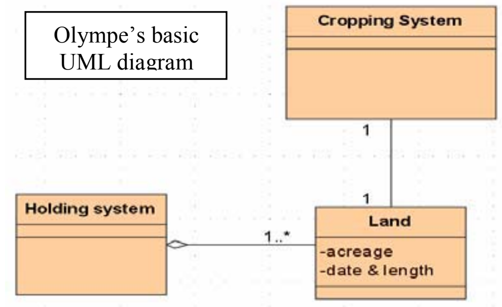

Figure 2: simplified diagram of Olympe

The different types of systems illustrated above were selected as being significant in the farm's present situation. This allows the study of characteristic values which, in the context of farming management, are relevant at different scales. The farmer is considered to be the main decision-making agent. Technical innovation consists in modifying cropping practices (with associated costs and benefits) or replacing one cropping/livestock system by another. Thus, we need to understand the strategies the farmer uses to link determining economic factors (investments, cash flow, funding capacity etc.) with the optimal combination of cropping/livestock systems, taking into account other sources of income such as hunting, fishing, handicrafts and non-agricultural activities; a diversity which characterizes many farmers. The interplay between the elements that make up a given farming system is called a pathway.

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

Framework, origin and working principle of the model

Multi-agent modelling means complex systems can be represented as a set of individual agents which interact in a particular environment and this representation results in the emergence of the picture of the whole system (Ferber 1995). Each 'agent' takes his own decisions based on his own goals and his own representation of the environment *(figure 3)*. This kind of modelling can be adapted to represent social organisation and that is why it is currently being used by the Cirad to tackle problems inherent in resources management in a participative modelling approach.

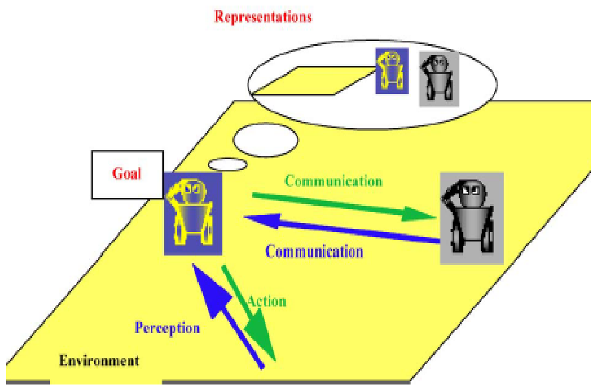

Figure 3: multi-agent system (Ferber 1999)

This type of representation enables us to study the consequences a given change will have for the system as a whole, whether the change concerns the rules of cooperation, the perception an agent has of his environment, or a different quantity of resources.

The 'Cormas' model and its use

Cormas is an agent-based simulation platform which was created to be used in a companion-modelling approach. Cormas is a computer tool which uses object programming to define each entity of the model as belonging to a 'class' which is defined by the modeller. In fact, certain basic classes (an 'agent', the active entity, 'a spatial entity', the elementary part of the topological back-up, and 'a passive entity') are pre-defined with basic characteristics and functions, and the user can create his own classes from these pre-defined entities to build his own model. He can for example define a 'farmer' as a 'located agent' whom he will link with an object 'farm' which he will already have defined *(figure 4)*. It is then possible to study the influence specific definitions (definitions of interactions between agents for example) have on future developments.

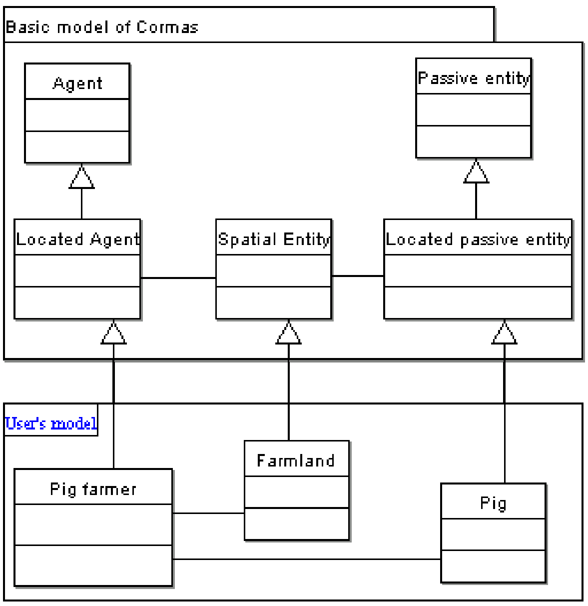

Figure 4: Diagram of a basic Cormas model

Complementarities of the two approaches

The advantage of combining the two approaches is the ability to represent, simulate and understand the roles of the different stakeholders and their strategies and, reciprocally, to see what influence the farmers' strategies have on the system as a function of the original situation and of the definitions of the rest of the system.

To this end, we used a multi-agent modelling approach (Cormas) to represent interactions, and a systemic representation of the holding (Olympe) to have a suitable basis for the definition of individual strategies *(figure 5)*.

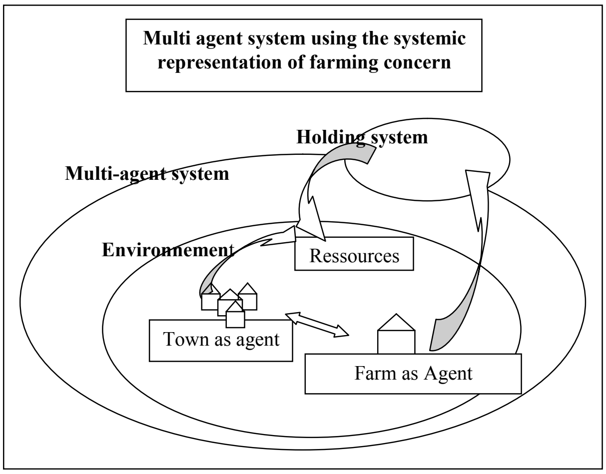

Figure 5: Coupling the models Farm as Agent should be Farm as agent

One of the main benefits in this work is to bring together people with different vocations to work on the creation of the same model. Agent-based models are often used to represent and analyse social problems at the regional scale, for example the impact pollution management or forest depletion will have on a limited resource, such as water or land. Those who create and use these models are often specialists in the problem concerned. In agriculture for example, using a systemic representation with a reasonably well defined unit enables an economic assessment that is relatively easy to process thereby enabling agro-economists to study the decision-making process in detail. Prospective analysis using Olympe provides scenarios that enable exploration of potentialities in partnership with farmers or with any other stakeholders involved in agriculture. Thus, knowledge accumulated over several years enables validation of hypotheses without losing touch with reality.

As Olympe is mono-agent with no interactions between agents, analysis of interactions, particularly with other agents, is consequently impossible. Linking Olympe with a MAS platform thus has two objectives: to obtain a better definition of the 'farmer 'entity in the MAS (obtaining the economic information on farmers' behaviours from the Olympe data base) while MAS allows analysis of interactions firstly between farmers and secondly between farmers and other agents (Government, traders, policy makers, developers, project managers, etc.). In other words, Olympe feeds the SMA with information about one particular but crucial, agent: the farmer.

METHODOLOGY USED TO COUPLE THE TWO SOFTWARE SYSTEMS

Objectives and technical choices

After having defined the entities involved (i.e. the level of analysis, local/farming systems and regional/MAS) and the philosophy behind the approach and use of the two software systems, we define the main functions we would like to integrate to ensure an effective and useful link. The objective is to assure the correct transfer of data (and 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' that are representative of 'standard' farming systems. Olympe is a very efficient tool to characterize from an economic viewpoint a range of different farms from smallholdings to large estates with varying degrees of precision depending on the primary objective of the user. The number of Olympe users is currently expanding and thus providing feedback from a very interesting and pragmatic 'network of users' who share their data sets and experience. This should result in an impressive data base of farming systems all over the world. The main advantage is that comparisons are possible because users can share the same tools, the same simple but efficient economic indicators and consequently the same language and set of definitions. Such data can be used to calibrate a multi-agent model. Finally, it would be useful to create a link to feed data back to Olympe after it has been used in Cormas; this would give Olympe users the opportunity to react. Although a dynamic link of this type would be very useful it requires compatibility between the two software systems (written in different languages) and may thus be difficult to implement.

So far our objective has been to create a modelling framework with data from Olympe feeding the 'farmer' agent in Cormas, which allows users to transfer all management indicators of farming systems under Olympe to a multi-agent model through the definition of a proper Olympe data import protocol in the multi-agent model.

We chose to use the Cormas platform for our simulations. Specific classes were 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, the Olympe conceptual model is introduced into Cormas' world.

Olympe's conceptual model in Cormas' world

A more detailed technical description of the link is needed here in order to understand the issues involved and consequently the limits of this work. Olympe will be used here only to model and not to simulate. Data are only generated by Olympe concerning the 'farmer' agent while Cormas generates the other agents in its own format. The simulation is implemented under Cormas. The data obtained and transferred with Olympe are the following:

- Quantity of products (inputs/outputs) and costs/benefits

- The structure of the cropping and livestock systems with 4 different formats for crops: annual crops, multi-annual crop (from 1 to 5 years), perennial crops (more than 5 years) and 'animals' (this is a potentially very 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 very detailed) including lifespan, costs/benefits and labour requirements.

- Characteristics of the global farming system (structural costs, financial costs and other sorts of benefits and expenses).

This type of conceptual organisation is illustrated in the diagram of Olympe UML classes *(figure 6)*.

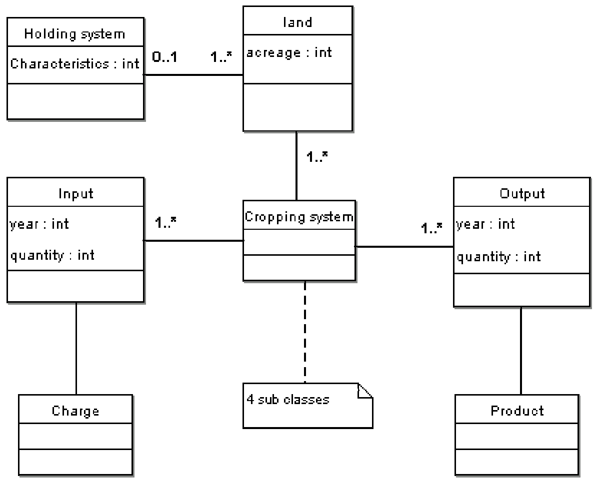

Figure 6: diagram of Olympe classes

It is important to mention that in such a framework, Olympe will only provide the economic results and the technical functioning of each sub-system at the farm level.

As the centre of decision-making in the systemic representation is defined at farm level, we chose to identify the 'farmer' agent 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)*. This 'kind of activity' will have all the characteristics of a cropping or livestock system defined using Olympe. Costs (Charges and Products) and kinds of production (kinds of activities) are defined using Olympe before beginning the simulation under Cormas and are not modified after transfer to Cormas; in other words, up to now, this is a one-way process. Agents (stakeholders) can only choose to farm their land by choosing the kind of activity they prefer from the list of available activities ('kind of activities') as a function of whatever available parameter the user wants.

EXAMPLE OF A SIMULATION CARRIED OUT WITH OUR PLATFORM

Description of the example

This example was developed for educational purposes to show the potential advantages of such a combination and as a method to implement it rather than to build a real case-study. MAS is used to represent interactions between farmers with behaviours defined according to the Olympe economic situation. The advantage lies in the definition of possible interactions and the impact of the results of the simulation on individual strategies.

The example is based on a real situation observed in the province of West Kalimantan (Borneo) in Indonesia, where rubber farmers have diversified with oil palm and other activities and also integrated new cropping methods and improved agroforestry practices (Leconte 2000). The situation described is typical of post-pioneer areas where diversification is used as a strategy to limit potential risks following a period of monoculture introduced during the first phase in pioneer zones when farmers relied on only one crop (in our case the jungle rubber system, an extensive agroforestry rubber based system), (Penot 2001). The same type of example could be developed for other typical pioneer areas (Amazon, Cambodia, West Africa, etc.). The characterisation of farming systems, and monitoring between 1997 and 2002 was carried out with emphasis on identifying farmers' strategies.

In our example, interactions correspond to knowledge transfer, and individual strategies are limited to the choice of which crops to rotate. *(Table 1)*

Table 1: interactions and strategies

Different sorts of "knowledge transfer": two types of transfer were selected for this example: - "Theoretical learning": farmers know how to implement technological recommendations or adopted recommendations two years after having been introduced to the new system by relatives. Once a farmer has acquired the know-how, he begins to teach it to his relatives. - "Observation as learning process": a farmer acquires the know-how because one of his relatives has already implemented the new cropping system on his own farm. ***Different individual strategies:*** - The "careful strategy": a farmer implements a new cropping system only if he can afford to pay for the plantation and to cover the costs of establishment. - The "innovative strategy": a farmer systemically implements a new cropping system as soon as he thinks that it would be more profitable than other crops, particularly annual crops, even if he will need credit. In other words, he takes at least some financial risks.

Different situations are simulated. Based on his own financial situation, which is well defined under Olympe, each farmer can choose his level of investment in a new cropping system. Multi-agent modelling allows representation of the transfer of knowledge, its evolution, and the geographical aspect of the problem (diffusion) in the form of a simulated map.

Depending on the initial situation, the rules that govern interactions and consequently farmers' strategies can influence the simulation and its results. The purpose of this example is only to illustrate that the two different representations of the farmer as an agent in Olympe and in a MAS can be combined and are useful to study farmers' behaviour from different viewpoints, as well as to show how simulations leading to scenarios can be built. This example is not intended to be representative since neither the data nor the rules have been calibrated or tested with respect to the sensitivity of the initial parameters.

Description of a simulation example

We simulated a situation in which we combined "observation as a learning process" and "Careful strategy". In this simulation there only are 3 different cropping systems:

i) 'Upland rice', which is not very profitable but ensures food security;

ii) "Jungle Rubber" (a classical extensive rubber agroforestry system) which is more profitable but only 15 years after it was planted (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 during the first years but require capital for implementation.

Initialisation of the simulation

20 farming systems were generated and placed on the topological support. Of these 20 farms, 4 were chosen as having the know-how to set up the new rubber cropping system (RAS). Others can only grow the classical upland rice crop and Jungle Rubber. Each farm received initial funds and a random set of the two cropping systems on 9 plots. In this example, jungle rubber crops were considered to be mature at the beginning of the simulation. Each farm is linked to two others (the nearest smallholding not too far away on the map) who are considered as "relatives".

Description of each step of the simulation

Each farmer undertakes the following activities:

- Crop his plots according to the chosen cropping systems

- Chooses the best cropping system he can afford based on his financial assets and the productivity of the system

- Learns how to set up the new cropping system if one of his relatives has already set it up.

Observations

Figure 8 is a simulated map of the situation at a key point in the simulation. Details of this particular simulation are presented in table 2.

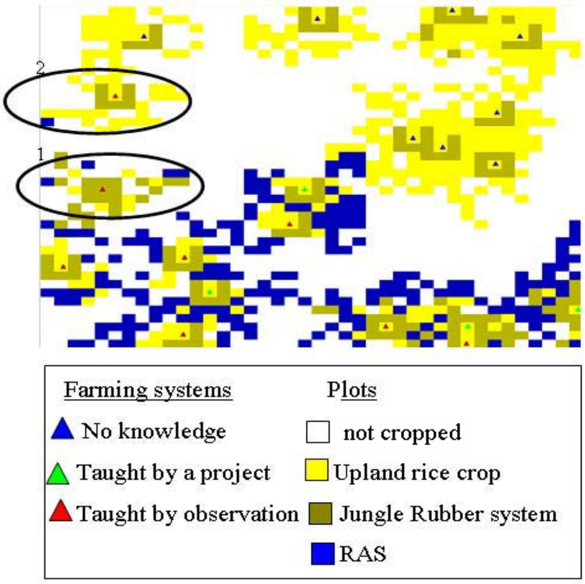

Figure 8: situation after 27 years of simulation

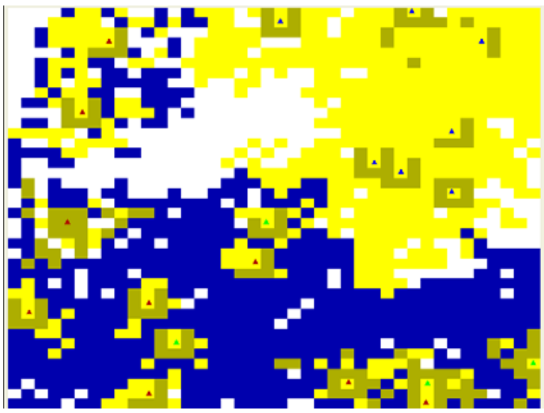

Figure 9: Situation after 56 years

The map in figure 8 shows the situation at the 27th step of the simulation. After about 30 years of simulation, it will be noted that the farmers who developed RAS are all located in the southern part of the map, due to the fact that the 4 smallholdings which had the knowledge at the beginning of the simulation were all located in that area and that the transfer of knowledge is linked to geographical proximity.

At the very beginning of the simulation, almost every farmer in the south had already implemented the new cropping system. However, the farmer in circle n° 1 on the map had only upland rice crops at the time of initialisation. At the beginning of the simulation, he began to plant “Jungle rubber” but he soon lacked funds to invest in other cropping systems. So by the time he had learned how to implement RAS, he could not afford to and now has to wait for his ‘Jungle rubber’ to be productive.

Due to their geographical location, all the farmers in the north except farmer n° 2 are all linked as relatives. Farmer n°2 must wait for farmer n° 1 to establish his first RAS to learn how to set it up himself. He has to wait 30 years in this simulation. Only then will northern farmers be able to access the information they need.

If we had chosen the “innovative strategy”, farmer n° 1 would have planted RAS as soon as he had learned how to proceed and the whole northern area would had have access to information much earlier. Similarly, “theoretical learning” would have allowed the northern area to establish RAS before farmer n° 1.

Figure 9 shows the situation after 56 years.

Of course this example is very simple but nevertheless shows how Olympe data can be used to feed the “farmer” agent in a MAS.

Table 2: details of the simulation

LIMITS AND FUTURE OUTLOOK

Sensitivity studies

An important point concerning simulations done with this new platform (Cormas & Olympe) is that there are a lot of parameters due to the precision of the information concerning the cropping systems generated by Olympe. It is consequently necessary to check the stability of the model and the validity of the values obtained by the MAS.

Multidisciplinary studies

Based on the structure of the data used by this type of platform, transfer of data between Cormas and Olympe (feedback) is possible but has not yet been implemented due to lack of time. Such a link would enable us to look at any farming systems at any time during the simulation and to check if the choices made by agents are rational. Rules governing farmers’ decisions can be defined very precisely since the economic information provided by Olympe can be very precise. But validation should be carefully implemented as the degree of complexity increases with an increase in the number of links to other agents.

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 'farmer' agent as well as to profit from a data base on different types of farming systems created under Olympe. However the two software systems are written in different languages with different formats. We developed a link for educational purposes to demonstrate the advantages of coupling the two tools to better explain complex systems and to understand the potential impact of technical change in situations where the farmer is a major stakeholder and the economic impact of change needs to be defined with precision. MSA allows analysis of interactions that is not possible with Olympe. The two software systems appear to be very complementary despite their different objectives.

This initial study paves the way for further work in coupling the two tools to respect the degree of complexity required by a given agrarian situation.

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Eric Penot is a senior agro-economist who has considerable experience on perennial crops in humid tropical regions, especially on rubber-based agroforestry systems in Indonesia. As a specialist of farming systems economics, he has been contributing to the developement of the software "Olympe" in the INRA/CIRAD/IAMM team since 1999.

Jean Francois Tourrand is a livestock specialist whose main experience is in West Africa, and for the last 10 years, in the Amazonian Basin. He is currently leading a team of Brazilian and French scientists studying the evolution of pioneer areas in Amazonia, and is currently developing a MAS.

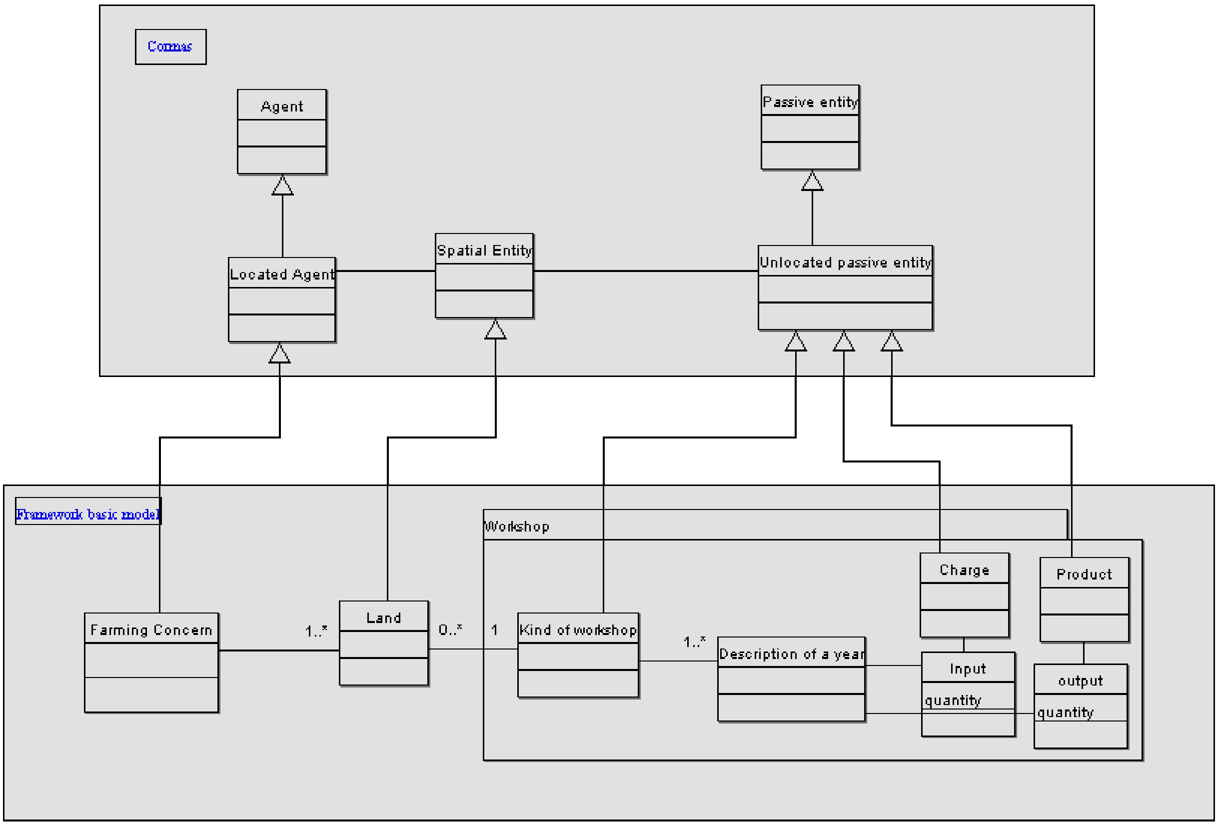

Figure 7: diagram of our platform