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Toward new instruments to help negotiation concerning irrigation.

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ABSTRACT

Many instruments of aid to strategic decisions are now operational and used by farmers and their counselors. The budgetary simulators are most frequent and techniques of optimization are mostly used in perspectives of research.
But these instruments meet limits. More and more problems: markets, utilization of limited natural resources cannot be considered only on the farm level but require a global approach.
Authors propose the complementary approaches of increasing complexity and present experimentation results led with three types of instruments on the same type of problem.
They develop successively the utilization of a regional simulator aggregating the individual results, the creation and the use of a business game, then the possibilities of multi-agent system will be considered.

INTRODUCTION

For about twenty years irrigation has been increasing in France and in Mediterranean countries.
The main reasons are that the farmers wish to increase yields and to secure incomes. In consequence, crops with high-level water requirement (corn e.g.) have considerably increased. Concurrently, farmers negotiate with agro-industrial enterprises to secure their revenue. In this case they have to irrigate to meet their contracts.
Therefore water becomes a scarce resource and the object of conflicts between its different users.
To avoid these conflicts different means are used: establishment of water pricing, allocation of water volume to farmers. But problems are specific to every region and a unique and centralised procedure is not accurate. At the local level, negotiations are always necessary but not easy between the different parties: water suppliers, public services, farmers and environmentalists.

We assume that these negotiations could be improved if one could provide individually and collectively the possible consequences of different regulations.

Different models based on linear programming or theory of games have already been used for this purpose. But basic assumption of complete rationality and difficulties to implement very large models taking into account different types of farmers limit considerably the relevance of such models.
To help negotiators we think that an appropriate model should present the following features:

- Ability to be understood by negotiators.
- Diversity of actor behaviours particularly "irrational behaviours".
- Include evolution of actor behaviours according to their "learning by doing".
- Show possible evolution of farms over several years including their eventual disappearance.
- Emphasize economical, social and environmental consequences of decisions.
- Include interactions between different actors.

In this perspective several researches are led in parallel. They are based on techniques of increasing complexity.

· The first approach uses the techniques of budgetary simulation used usually by advisers to help farmers take some strategic decisions. Used in an interactive way by an adviser with the farmer it provides several solutions amongst which the farmer takes his decision in accordance with his own criteria and his personal objectives. For every solution different variants, based on scripts of evolution of output or variation of price, can be established and can be provided to the farmer to evaluate the robustness of the solution.
This model has been completed to be able to simulate the evolution of several types of farmers whose numbers can vary.

· The second approach is inspired of business games used in industry, it is based on the use of the simulator described previously. Players: students, farmer advisers, managers have to take decisions for their enterprise without knowing the decisions of the other player decisions. But markets are limited: for every product there exists a curve quantity price. For some inputs: eg water quantities are limited. The game takes place over a certain number of years: every " year " every player decides his production plan , the model totals the produced quantities, determines the price and calculate returns and expenses of every player that, considering his results must decide then for the following year.

· The third approach is based on techniques of distributed artificial intelligence and is based on the creation and utilisation of a multi-agent system (MAS). It makes the object of another communication and won't be presented in detail. Let's underline how these two approaches complement each other. In the business game the players have some important action possibilities: they make call to all of their knowledge. On the contrary in the setting of the MAS action rule of every agent has been programmed and is therefore limited. But examining player strategies it is possible to enrich the behaviour of MAS agents.

REGIONAL SIMULATION MODEL: A simulator to help the negotiation in an irrigated zone in Tunisia.

1. The Context

Tunisia is a country on the south strand of the Mediterranean Sea which is especially concerned by problems of water management because it reaches limits of its resource. This country invested strongly in irrigation and today the main effort concerns management improvement of its irrigated area. We could note in an irrigated area that with the subsidies disappearance and a very low price increase, farmers income decrease. The sugar beet crop was encouraged in the irrigated area studied. This crop is a big water consumer with not competitive production costs. In such a system, the interests from different actors diverge during time. Dam administrators must manage the water resource, provide restrictions in order to avoid shortages and obtain a satisfactory revenue. The sugar factory must assure its sugar beet provisions. Farmers want to have a better income and the Government in a more general manner prefers to valorise water resource To build a negotiation framework about productions choice in accordance with water availability, it is first necessary to imagine and evaluate different solutions and to search for negotiable solutions.

A simulator to help the negotiation in an irrigated zone in Tunisia.
Actors from the system.

Administration :
His Objective
Increase sugar production
Improvement of water recovery
His means :
- Sugar factories
- Dams. Irrigated zones
- Level of Water price

Sugar factory :
- To maintain the sugar beet supply

Dam Manager :
- To manage quantities
- To increase income

Producers: 1500 farmers, 4900 ha,
35 individuals simulations : 24 aggregated
- To improve their income and to decrease the water risk shortage

Fig.1: Actors from the system to help negotiation in an irrigated zone in Tunisia.

To help the dialogue between the different involved actors we designed a area model to simulate different evolution scenarios.
Work is led in three phases:

- Collection of technical data on farms as well as data collect about their socio-economic environment.
- The design of a model of the irrigated zone that will be at a time a data base on systems and a tool of simulation.
- Simulation of scenarios to increase dialogue between different actors and to facilitate emergence of new solution.

2. Typology and production Systems

The first phase consisted in establishing a typology of farms, identify one or several farmers from every type and to build up with him different evolution scenarios of his farm. We used our budgetary simulator that runs over 9 years: 6 years of forecasting and 3 past years to validate the model.
This phase allow us to collect some basic information on the different crops and to validate these data while comparing past results provided by the model to the real results. This phase brought us to establish a typology of years and to define for every type of year inputs and outputs for every crop. The investigation was done on a surface reaching 662,7 ha so 14,5% of the sector surface and on 25 farms.

We kept three types of year in the beginning according to the rainfall amount of the year and water stocks in the dam during the agricultural year:
Year of type A: important stock in the dam and weak rainfall amount.
Year of type B: weak stock and normal rainfall amount.
Year of type C: important stock and strong rainfall amount.

This phase based on individual interviews in farms also provided a lot of information on the constraints undergone by farmers and orientations that they wished to take.

3. Global model and its validation

Arranging a set of data on productions, the historic of three agricultural years of the twenty-five farms investigated and with a lot of individual simulations we could develop a model for the sector. We regrouped all elementary data treated before reproducing the activity to the sector scale.
Three parts compose the computer program used:

- A technical part to define for farms from every zone (crops, animals, orchard), the inputs and outputs for different production levels.
- A part concerning the types of farms. Every type of farm has a name, is in a zone and has a weight. It corresponds to various farms seen earlier. We have first introduced cropping plan rotation, orchard, livestock composition, fixed costs achieved in the past.
- A part of risk definition. This one results here by the definition of several types of year that entails variations on inputs and outputs. These risks are used in the calculation of last year results to validate the model and in the prospective scenarios establishment taking into account the climatic variability.

This program provides, by choice, for a farm or for farms in a special zone, or a type, or for the set of farms of the whole sector, results in quantity and in value for the last three years and forecasting for six years considering the considered climatic scenarios (Fig. 2).

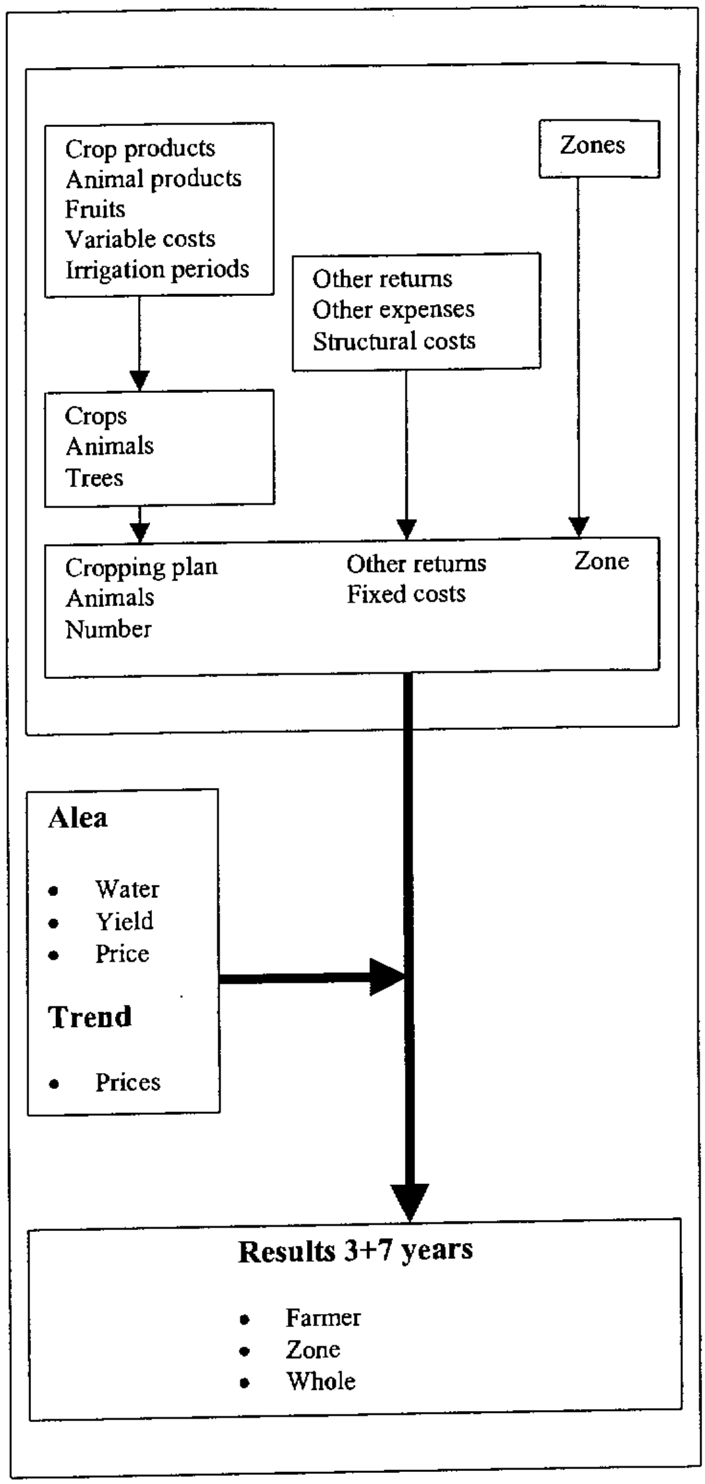

Fig. 2: The global model.

4. Model validation

For validation, we compared model results to available data on the zone. They come from zone

statistics concerning crops surfaces and sugar factory productions for the sugar beet production and the dam administrator for water consumption .
Concerning total surface , model results reach an average of 98% of the real surface with an inter-yearly variability that doesn't exceed 6%.
But there are some big differences for some crops. The difference is very important for two crops. The shift is accentuated for the late potatoes and is explained by crop nature. It is a catch crop that is often forgotten by farmer during the interview. The last remark that requires more reflection, is the overtaking of sugar beet surfaces for the three agricultural years. This overtaking oriented us toward the hypothesis that farmers overvalued sugar beet surfaces by distrust and to show that they respect regulation. Indeed the water price is function of the sugar beet surface. A set of interviews verified this hypothesis and provided some modifications introduced in the model. The following figures (Fig.3, Fig.4) show real and calculated surfaces and productions before and after validation.

Crops	Statistics data	before Validation	%	After validation	%
Wheat	2050	1890	92	2004	98
Sugar beet	984	1162	118	1063	108
Early potato	207	133	64	159	77
Late potato	214	128	60	128	60
Total zone	4695	4609	98	4608	98

Fig.3:Surface comparison between model and reality
before and after validation (in ha)

Crops	Statistics data	Before validation	%	After validation	%
Wheat	8477	6567	77	7067	83
Sugar beet	48204	58200	121	54220	112
Early potato	3122	2183	70	2581	77
Late potato	2635	1350	51	1350	51

Fig.4 : Production comparison between model an reality
before and after validation (in ha)

For water consumption, the model provides in a first time some lower consumption to the reality. A detailed analysis completed by interviews showed that in years of strong rainfall amount where the stock in the dam was important, the farmers irrigated less than the crops needed. For the dry years but with important stock in the dam there was a very strong use of water On opposition, model results coincided with a normal rainfall amount with weak reserve. In this case the irrigation rules were respected by restriction measures imposed by the administration. In a general way, we could note a tendency to the water wasting in absence of shortage on the resource. This is due by farmer's practices and by non-farmer uses and losses in the network. It has been restored in the model like shows fig.5.

Designation	A	B	C	Average
Results of the model	10,5	7,8	5,1	7,8
Other uses	0,5	0,5	0,5	0,5
Losts (15%)	1,65	1,25	0,84	1,25
Total re-established	12,65	9,55	6,44	9,55
Invoiced real consumption	14,02	9,71	5,83	9,85
%	90	98	110	97

Fig.5 : Water consumptions
in the sector for each year (in Mm³)

5. Simulations to enter into a dialogue between actors :

The different years studied constitute different types that we qualified from rainfall amount but also from water available in the dam. To be able to affect frequencies to these years we analysed rainfall recorded on 33 years. We could bring to light the following results: year - type A (25%), year - type B (50%) and year - type C (25%) as detailed on paragraph 2.

In the zone we identify three main actors whose interests are different. The dam managing administration who must balance his accounts and is interested by water consumption and water pricing. The sugar factory which is interested by the quantity of sugar beet produced. And farmers of the sector interested by their revenue. Otherwise extension services provided data collected at the farm level corresponding to more intensive production

To help negotiation between these three actors we established different evolution scenarios while considering different cropping plans and different intensification levels.

1. The possibility to increase sugar beet production.

The sugar factory has an important role in this region and tries to arrange a more important sugar beet quantity . Different more intensive techniques are known but they require more water and the possibility to use it is problematic.
We simulated different scenarios with an increasing intensification. The synthetic results presented here (Fig.6) show the advantage for the sugar factory and for the water supplier who increase their revenues. However the water supplier risks not to be able to provide the amount of water needed every year. On opposition, farmers obliged to

intensify their crops don't benefit from their efforts: their revenue increases very weakly.

Scenario	Water need	Redevance	Sugar Beet	Inputs Exploitations
Actual	100	100	100	100
Intensification II	115	115	114	102.5
Intensification III	128	128	125	104

Fig.6: Consequences of sugar beet intensification.
Average results. (basis 100 to the present situation)

2. Sugar beet suppression

To follow these first simulations farmers and dam manager are wondering about the interest to maintain sugar beet. In this goal, we established with local agronomists different crops rotations including pulses and vegetable-field crops. Results (Fig.7) show a strong decrease of water consumption. Dam revenues decrease a little because water price is higher: it doesn't benefit of reduced price allowed for sugar beet crops. Therefore, the dam administrator is interested by this solution because his incomes lower weakly and he can consider selling water to other irrigated zones. Farmers are also interested: they discover that not cropping sugar beet t doesn't decrease very much their incomes. To the issue of these simulations raised intensification interest.

Scenario	Water need	Redevance	Sugar beet	Incomes Exploitations
Actuel	100	100	100	100
Variant 1	64	83	0	98.6
Variant 2	64	83	0	97.4
Variant 3	64	83	0	96
Variant 4	64	83	0	94.8
Variant 5	64	83	0	93.4

Fig.7: Consequences of sugar beet suppression.
Average results for actual level of intensification.
(basis 100 to the present situation)

3. Consequences of different levels of intensification

We simulated two intensification levels for different cropping plans. Results (Fig.8) show the interest for the dam manager and for farmers to intensify and to suppress sugar beet. To survive the sugar factory should increase sugar beet prices but it cannot do it without increasing its production cost or to receive an important grant aid . The sugar cost increase would entail a loss of its outlets .

Scenario		Water need	Redevance	Sugar Beet	Inputs Exploitations
Actual	avec betterave	100	100	100	100
Level I		64	83	0	98.6
Level II		84	108	0	109.3
Level III		104	133	0	116

Fig.8: Intensification consequences for the variant 1
(basis 100 to the present situation)

4. Results sensitivity of price variations.

The previous results are directly issued from the model. But they are based on price hypotheses and are therefore questionable. So we used another simulator function to do a sensitivity analysis: we progressively decrease the gross product from other crops until the solution results with sugar beet are reached.
This analysis showed that for the different intensive variants the sensitivity is weak: it is necessary to lower gross product from 31% and 45% according to intensification level to obtain the same income that solutions with sugar beet

5. Possible extension of this approach

For an outside observer results seem clear; sugar beet must disappear. In fact the decision is incumbent upon the local actors: the model only provided negotiation elements.

It is based on a farm typology and a detailed analysis. design of a global model of the zone and its validation by comparison to the existing global data showed individual interviews limits and obliged to do complementary interviews on the really cropping surfaces and on irrigation practices. Once this sufficiently validated model can be interrogated. It provided progressively to the different actors consequences of crop rotation modifications and intensification levels.

The presentation of this model to actors showed us the necessity to present in a first step and in detail the data used in the model. It is only after having showed and discussed inputs and outputs of the

main crops and presented typology used that global results can be presented and discussed. The conclusion about the low interest of sugar beet has been shared by participants whose sugar factory manager and now (some years after this study) whose sugar factory no longer exist. The working group created on this occasion still exist and asks for a new simulation to refine other decisions. Other irrigated zones need similar studies and we try to respond while training local students to understand local problems and local agricultural practices. This work results in fact from an experiment achieved by the authors and a Tunisian student and required six months of work. It seems therefore easily repeatable and several comparable studies are currently in progress.
On the computer point of view the program used was a prototype. Its use showed its strengths and its weaknesses. A more elaborate version is currently in a test phase and will be shortly available.

Development of a business game

The previous experience showed necessity to develop methods and instruments to be able to construct quickly with decision-makers scenarios to answer their questions and to modify these scenarios in accordance with decider thoughts This one also showed us opposite interests from different actors and existence of different coalition.
As following comparable studies led with same approach and the same instrument , we tried to use to use data collected and same simulator to create a business game . This toll allows to put players in decision situation , to oblige them to negotiate to establish production plan considering global constraints and others players decisions. The game objective is that actors can learn on the " virtual " to act better on the " real ".

First game users were students and the case study is a simplified case inspired from a Mediterranean zone. In their cursus the students had already achieved a linear programming model on this zone and this game was also the opportunity to recall the underlying strong hypotheses of this technique.

1. different production systems in an agricultural region

The virtual region includes four main systems with different potentialities, technical levels and farm numbers .
The system A has a lot vegetable-field crops with 500 farms of 10 Ha each
The system B has vegetable-field crops and cereals with 100 farms of 50 Ha each.
The system C has vegetable-field crops and orchards with 100 farms of 30 Ha each.
The system D has cereals and fruits with 50 farms of 200 ha each (orchard: peach trees 5 ha and apple trees 25 ha)
Every production system has production factors, crop potentialities and production techniques according to three intensification levels. Main inputs are: land ,workforce, water quotas with different prices.

The agricultural region is also determined by production history, by evolution consumption and production factors availability, as well as markets and prices evolution .
Using the game, the water availability is uncertain and is randomly fixed every year. The different products have a function that joins price and global quantity produced with different elasticity according to products. All these elements are unknown by players who discover them progressively.

2. Progress of the game

Every type of agricultural farm is "managed" by a student group. This one knows all technical potentialities of its production system and those of other farms as well as the historic regional level.
Then every group must decide and must define his production plan without knowing the decisions of the other groups in the past and what they are going to decide for next year. Every group doesn't know either how is going to evolve precisely the production factors availability who are outside to the farm, products quantities and prices on markets.

The game is going to take place step-by-step:

Every group decides a cropping plan according to his technical, financial capacities, his water and workforce availability.
All decisions are aggregated in the regional simulator and total production is calculated in accordance with climatic conditions randomly selected.
Market models defined by product calculate quantities sold and selling prices on different markets.
In return these elements allow to calculate global income for every farm. Then results are given to every group that must take a decision for next year. These results contain group farm results and regional results.
The game is structured in two phases:

- A first phase without communications between players
- A second phase where players can discuss and negotiate

1. no communications between players

The first game period has been characterised by over productions on certain products and deficits on others. Water and manpower availability are immediately reached, and deficits appeared; this is due in general to use of intensive production levels which brings theoretically more cash. Individual optimisation models based on linear programming was used by groups reinforced the research of highest results therefore increased an intensification process.
Excess product prices fall down and those of deficit productions increased strongly.
In the following periods we saw emergence of production diversification to minimise risk. Water consumption decreased and was more or less in accordance with availability..
Farms and region results were improved, but surpluses and important deficits persisted.

2. possibility to discuss and negotiate

This second phase started by a first meeting between players and information was exchanged about the different production systems . An common analysis of region and markets resources evolution was made. This first exchange allowed to decrease information asymmetry between actors, but failed on two points: determination on the items on which it is possible to discuss and how to discuss.

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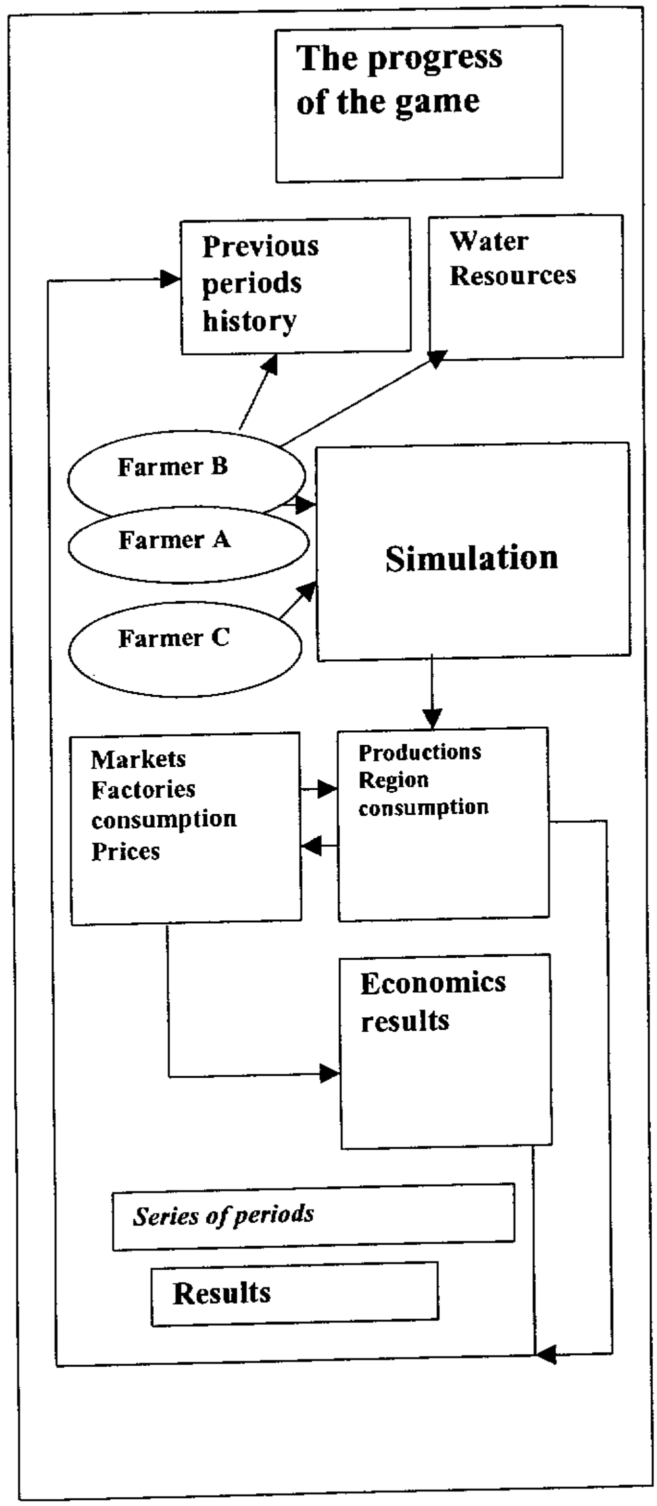
In the following periods we noticed progressive emergence of agreements between players: quotas definition on some products, negotiated monopoly creation on a few products. Lastly, a water market appeared.
These negotiations brought a strong reduction of surpluses and an increase of farm revenues.

3. Learning from the results of business game

The game experiment taught several lessons:
Without negotiation the individual training allows to improve global performances, but it appears quickly a maximum level in a system where resources and markets are limited and uncertain.
Use of negotiation process allows to improve strongly system performances until a new level.
In parallel, an optimisation model of the region was used and provided us for each period the optimum level that could reach the region if one had a perfect knowledge about available and markets .
The comparison between the optimal solution and simulations results show there is still an important progress margin after the second phase. We think that the game continuation would have allowed improvement. But due to the lack of time we were not able to verify this hypothesis. Otherwise, we think that an elementary training to game theory would have allowed players to progress more quickly. Also, this hypothesis will have to be tested.



CONCLUSION

In a context where markets and prices change rapidly and production techniques are moving, farmers are brought to react quickly . A lot of more or less sophisticated methods and instruments are now at extension services disposal and used at a variable extent.

But help to individual decision quickly finds limits as many problems occur more at a larger level that at an individual one. So, markets, environmental conservation or natural resource management must be considered at more global level and bring to a dialogue between different groups of actors with contradictory interests.

In this perspective simple techniques as the simulation used in an interactive and progressive way with decision-makers can bring interesting results at low cost. One of its advantages is that it is easy to understand: the computer only plays the role of improved calculator and data used are easily visible. The different experiments that we conducted showed us that they could be used, after a short training, by farm advisers or students . In this case its use on concrete problems with decision-makers proved to be an excellent training to a global approach.

The business game is based on the same type of data and on the use of the same computer program. It constitutes an natural overtime of previous approach to show the co-ordination necessity between different decision-makers and the interest to negotiate to establish a set of applicable rules . If it is very formative but it seems rather time consuming. Its use by students is possible but the possibility to use with real decision-makers is to demonstrate.

The time constraint seems on the other hand less restricting with Multi-Agent models. It is possible to establish several result sets taking account of the environment variability and to test a resource assignment limited rules set . A first test showed the possibility of such an approach that is still in the research field.

In fact, these different approaches are very complementary and can be used successively. The initial data collection phase and their validation is a fundamental step. Being in possession of such data it is possible to create a decision-makers working group asking questions and analysing answers. So a real dialog can start on the real problems and avoid to solve false problems with academic way .

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