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AGENT BASED SIMULATION OF DECISION PROCESS MIXING RATIONAL REASONING AND INFLUENCES FROM SOCIO-INFORMATIONAL NETWORKS: CASE STUDIES OF AGRI-ENVIRONMENTAL MEASURES ADOPTION BY FARMERS

G. Deffuant*[✉], S. Skerratt, F. Amblard*, N. Ferrand*, E. Chattoe, N. Gilbert**, G. Weisbuch***

**Cemagref – LISC, Aubière, France*
***University of Surrey, Guildford, UK*
****Ecole Normale Supérieure, Paris, France*
Royal Agricultural College, Cirencester, UK

A model of the decision process mixing rational anticipation and social influences is proposed to study the dynamics of agri-environmental measure adoption by farmers in Breadalbane ESA. The decisions of the farmers are based on uncertain anticipations related to different criteria (revenue, independence, nature). These anticipations can be the result of a rational evaluation or a feeling or impression gathered from interactions with other farmers and institutional actors. The model simulates emissions and receptions of messages about these anticipations. Different states of the decision are defined, taking into account the anticipations and the motivations of the farmers. The model is linked to different sources of data : interviews with farmers and institutional actors and data on the population of farms. The different parameters are fitted with the data of participation to ESA meetings and ESA adoption.

Keywords: social simulation, multi-agent systems, decision-making process, social influence

1 INTRODUCTION

This paper proposes a model of the decision process for the adoption of agri-environmental measures (AEM) by farmers in Breadalbane Environmentally Sensitive Area1. The agri-

[✉] guillaume.deffuant@cemagref.fr

1 The project is being carried out with financial support from the Commission of the European Communities, Agriculture and Fisheries (FAIR) specific RTD programme. It does not necessarily reflects its views and in no way anticipates the Commissions's future policy in this area.

environmental measures are part of the Common Agricultural Policy. Their objective is to favour environmentally friendly practices in agriculture. Farmers can modify their practices (for instance avoid grazing on some parts of the farm to preserve the biodiversity), and in exchange, they receive some payments. These measures are optional, and therefore, the success of the policy depends on how attractive the measure is for the farmers. It appears that although money is a very important factor in the decision, it is not the only one. It seems that other factors, which are more cultural or social, such as the representation of farmer as a good producer, are important in the decision. The aim of the model is to investigate the decision process of the farmers in relation to past measures, and to propose prospective views of the impact of new measures and policies.

This model relates to the field of simulating societies (Doran and Gilbert, 1994) and multi-agent systems (Ferber, 1995). An important focus in the model is to mix rational reasoning (anticipations) and social influences. We build on previous work (Weisbuch and Boudjema, 1999) (Chattoe and Gilbert, 1998) which already addressed the same problem. The main difference is that the proposed work is more closely related to data and expertise collected for a particular case study (Breadalbane ESA). This link led us to propose decision process models in which the cognitive aspect is more elaborated, and related to multi-criteria analysis.

The farmers are modelled as cognitive interacting agents who can make rational anticipations (with uncertainties). The model comprises also a set of motivations which indicate the weight of the corresponding anticipation in his decision. We distinguish different states of the decision, corresponding to a level of interest. These states of decision evolve in time according to the messages received by the farmer.

The model simulates the exchanges about anticipations and uncertainties that happen in meetings or encounters between farmers themselves and with institutions. The modifications of their anticipations is ruled by simple dynamics which have been studied more theoretically in another paper (Deffuant et al.). The main goal of this paper is to evaluate the ability of the model to explain the dynamics of adoption on a real case (and not totally fictive ones as in the previous research).

We intend to develop several variants of this model, at different levels of complexity, and to compare them to each other, following a decreasing abstraction approach (Lindenberg, 1992). We describe in details only one version, but we give some indications about how the other models will be developed.

In the first section, the data and expertise about Breadalbane ESA are described. The second section describes the model. The third section is devoted to the simulations and their results. The paper ends with a conclusion and a discussion.

2 PRESENTATION OF THE PROBLEM, AVAILABLE DATA AND EXPERTISE

This section describes the problem of modelling the dynamics of adoption in Breadalbane ESA and its context. The sources of data and expertise available either to build, or to evaluate, the model are pointed out.

2.1 Problem and method

In this work, the cognitive and social models we propose are constrained by two types of data and expertise :

- global statistical data on the population
- analysis made in individual farmer interviews
- statistics on participation to ESA meetings and ESA adoption.

These different constraints do not play the same role. The idea, following multi-agent approaches, is to propose individual cognitive models, constrained by the analysis of individual interviews, and then choose the parameters that lead to the best fit of the data about ESA meeting participation and about ESA adoption. The ultimate goal is to use the model in a prospective way, that is to test the results on hypothetical measures.

As usual, the interaction between the modelling work and data collection happens in a loop. A first period of data collection (mainly interviews) happened with very general aims of understanding the decision process. From these interviews, a set of models has been proposed, followed by a new set of interviews, which were more specifically focused on the questions generated by the model.

We do not describe the whole process of these interactions between modelling and data collection here because it is not the focus of the paper. This is why the data are described first and then the model and the results. However, it has to be kept in mind that the process of modelling and data building has been more iterative than it appears.

2.2 Presentation of the zone and the measure

Breadalbane ESA covers an area of approximately 200 000 ha, and was selected as one of the two experimental zones for testing agri-environmental measures in the UK, in 1987. A first was launched during the period 1987 – 1992. A second one during the period 1992 – 1999. In this paper, we study only the period 1987 – 1992.

The measure consisted in several type of activities favouring landscape and biodiversity :

- a management commitment distinguishing between the quality of land (inbye or rough grazing) with an annual payment, proportional to the contracted area,
- rebuilding the traditional walls, with payment proportional to the length of walls to rebuild,
- fencing off parts biologically rich parts of the land to favour the maintenance of biodiversity, with payment proportional to the length of fences,
- bracken control with payment proportional to the treated areas.

Some studies of the economic impacts are available. They state that the this impact is generally positive, and can be quite significant (around 20% of farmer's annual income).

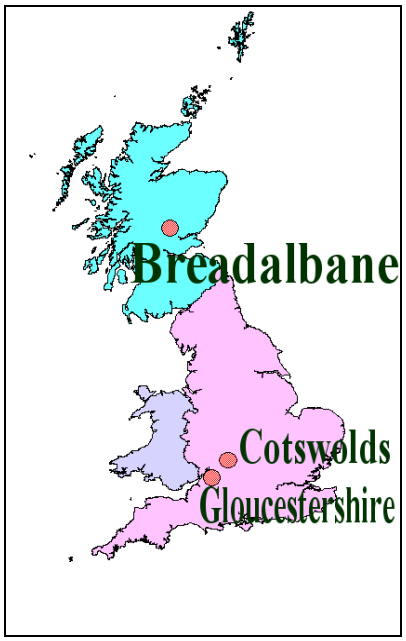

Figure 1. Location Of Breadalbane

2.3 Population of farmers

The population of the area is around 150 farmers, from which 40 have been interviewed in a first phase, and 10 reinterviewed in a second phase.

The average size of the farms is around 650 ha, with a minim of 30 ha and a maximum of 6300 ha.

	Ha	% of total
Owner occupied	88 758.1	50.1
Rented surfaces	80 651.8	45.5
	Ha	% of total
Crops	3 129	1.8
Forage	8 415	4.7
Rough grazing	163 368.2	92.2
Other	2 269.9	1.3
	Umber of heads	
Cattle	12 912	
Sheep	150,255	

Table 1. Some Figures About Breadalbane Area (1987)(Source: SERAD)

2.4 Main steps of the implementation

The organisations formally involved in the implementation are :

- the Scottish Agricultural College (SAC) which was in charge of the promotion of the scheme

- the Scottish Executive Rural Affairs Department (SERAD) which was in charge of the approval of the applications.

Other actors or organisations such as the press and the landlords have been informally involved in this implementation, because they broadcast messages about the measure.

After an analysis of the interviews with institutional actors and farmers, we consider that the main step of the ESA implementation process are :

- Autumn 1986, Press publishes first descriptions of the scheme. The main principles of the measures have been decided, but many uncertainties remain.
- End 1986 : SAC contacts a subset of farmers (10) to begin the promotion of the measure. The message is that the measure is financially interesting, and not too demanding.
- March 1987 : Official meeting for the promotion of the scheme instigated by SERAD and SAC. They give more explanations about the scheme. The message of SAC is globally the same. 65% of the farmers participated to this meeting.
- From March 1987 to end 1992 :
  - The interested farmers must contact SAC.
  - The advisor of SAC comes to visit the farm and establishes an ecological and landscape diagnosis, which is then sent to the farmer
  - The farmer then chooses whether or not to contact SAC for a second visit. This is where the farm plan (commitments of the farmer) are negotiated taking into account the ecological and landscape diagnosis.
  - The farm plan is sent to SERAD for approval. The contract only begins when this approval is given.

The whole process takes at least 4 to 6 months. It can be much longer (more than one year for some farmers). Only a small percentage of farmers who began the process finally did not adopt.

2.5 Adoption data

A large number of farmers subscribed during the first year (about 50% of the farmers submitted a file to SERAD). After that, the progression is slower but continues until 1992.

Date	Number of files submitted	% of total number of farms
31 May 1988	76	50 %
31 May 1989	84	56 %
31 May 1990	98	65 %
31 May 1992	117	78 %

Table 2. Number Of Files Submitted To SERAD (Source: SERAD)

2.6 The interviews

Two sets of farmer interviews have been carried out :

- A first set of 40 farmer interviews about the general aspects of the farm and its management, and agri-environmental policy. Several questions have been asked about the decision of adoption or non adoption. A procedure which facilitates the quantification of a set of motivations of the farmers has been developed (Dobremez, et al. 1999). Approximately 12 motivations connected to technical economical, environmental and social aspects are evaluated for each interviewed farmer.
- A subsample of 10 farmers among the 40 farmers have been re-interviewed. These second interviews were closely connected to the needs of the model about the motivations, social networks and the dynamics of the decision process. From a first analysis, it appears that the social networks of the farmers are constrained by the geographic distance. Moreover, the farmer associates tend to discuss more with farmers having similar farming systems. The age plays also a role, but less clearly than the social system.

Twelve institutional actors have been interviewed for the project. The focus of these interviews is on the implementation of the measure and the set of actions taken by the institutional actors.

3 THE MODEL

This section presents the different parts of the model : the model of the decision process, the interactions, the population, the social networks and the institutional actions.

3.1 The decision model

The model of decision is inspired by the multi-criteria decision support. It is considered that a decision is evaluated according to different criteria. The main difference with the multi-criteria literature is that the criteria can have different interpretations according to the stage of the decision :

- In the first stages, when the farmer has not really considered seriously the decision, the criteria correspond more to a series of impressions, or feelings, with more or less conviction.
- In later stages, when the farmer becomes more interested and envisages more seriously making the decision, the interpretation of some criteria has more to do with anticipations of the consequences of the decision (these anticipations being more or less certain). Some other criteria can remain closer to feelings or impressions, even in these later stages.

Uncertain anticipations

The model codes these two interpretations with the same variables that we call for simplicity "anticipations" and "uncertainties". In this simple version of the model, we consider 3 different anticipations which vary between –1 and +1, and the corresponding uncertainties which vary between 0 and 1 :

- a_r is the anticipation of impact on the revenue and d_r the uncertainty on this anticipation. When this anticipation is a rational calculation it is expressed as a percentage of the average revenue in the zone.
- a_i is the anticipation of impact on the independence of decision and d_i the uncertainty about this anticipation. This variable aims at expressing the change in the farming practices that the measures represent.
- a_e is the anticipation of impact on the environment and d_e the uncertainty about this anticipation.

Let **a** be the vector of anticipations. This vector evolves in time with the interactions. At the beginning of the simulations, it is considered that the farmers know nothing about the measure, and so all the anticipations are initialised at 0, with maximum uncertainties (1).

Motivations

The second set of variables that are considered in the model is the set of motivations of the farmer. In a multi-criteria approach, the motivations correspond to the weights associated to criteria. We consider therefore 3 motivations corresponding to the anticipations :

- m_r : motivation increase the revenue.
- m_i : motivation for the identity of producer
- m_e : motivation to act in favour of the environment

Let **m** be the vector of motivations. In this model, this vector is considered as fixed.

The different stages of decision

Vectors **a** (anticipations) and **m** (motivations) allow to define different stages of decision (when **a** varies). Four stages are considered :

- Stage 1 : preattentive stage, determined by : $\mathbf{m}.\mathbf{a} < S_1$, where S_1 is a threshold (parameter of the simulation) and **m**.**a** is the scalar product of the motivations by the anticipations. In this stage the anticipations should be considered as impressions or feelings, more or less conscious. The farmer does not envisage the decision, he does not think of it. He does not send messages to the other farmers or institutional actors about the measure. He has a low probability to attend to the meetings devoted to the measure (only to join friends). However, he receives messages from the others and institutions, and these messages modify his feelings.

- Stage 2a : stage of information search in the farmer network, determined by : $\mathbf{m}.\mathbf{a} > S_1$ and $\mathbf{m}.\mathbf{a} < S_2$, where S_2 is an other threshold (parameter of the simulation). The farmer increases his interactions within his farmer network, in order to discuss about possible adoption. The interactions take place with farmers who are in stage 2 or 3, because these who are in stage 1 do not answer. At this stage and in the following, the farmer has a high probability to attend to the information meetings about the measure.
- Stage 2b : launching the on farm institutional process (visits of the advisor), determined by : $\mathbf{m}.\mathbf{a} > S_2$. At this stage, the farmer requests the visits of the advisor (we simplify by considering only one visit in the model merging the ecological diagnosis and the final negotiation). Once this visits takes place, the farmer has a real anticipation about the economic impact of the measure, still with some uncertainties. To evaluate this anticipation, we make a calculation which take into account the size of the farm and the specifications of the measure (payments and costs, ceiling of payments…). The farmer continues to communicate much with his colleagues at this stage. The anticipations on independence and nature are still impressions or feelings, generated by the interactions with other farmers and institutions.
- Phase 3 : When the institutional procedure is finished and : $\mathbf{m}.\mathbf{a} - m_r.d_r > S_3$ (with S_3 a threshold, parameter of the simulation). This expresses that for his final decision, the farmer does not want to take a risk on his revenue. After the institutional procedure, the farmer enters the post decision phase. The frequency of his interactions (about the measure) decreases.

The decision functions are very simple. It is planned to test different variants of them. However, the level of approximation is compatible with other ones made in the model. It must be noticed that the final stages mix rational anticipations and social or cultural feelings coming from the group within the same decision function.

3.2 The interactions

The model simulates interactions between farmers themselves and with institutions. The interactions are modelled as exchanges of messages on anticipations and uncertainties about the measure. The first type of dynamics considered in previous models was simple diffusion (Chattoe and Gilbert, 1998).

This type of dynamics seemed too simplistic because it can only result in consensus. Instead, we proposed a modification in which several clusters of opinions (anticipations) can stay together. These dynamics translate the following heuristics :

- The higher is the uncertainty on the anticipation, the likelier is the influence of others
- When anticipations are very different and certain, people do not influence each other.

This can be translated mathematically as follows :

Let Δa_i and Δd_i be the changes in the anticipation a_i and the uncertainty d_i happening with the reception of a message a'_i with uncertainty d'_i. These changes follow the equations :

If $|a_i'-a_i| < d_i$ then : $\Delta a_i = \mu.(a'_i - a_i).\frac{d_i}{d_i + d'_i}$ and $\Delta d_i = \mu.(d'_i - d_i).\frac{d_i}{d_i + d'_i}$ *(1)*

else $\Delta a_i = 0$, $\Delta d_i = 0$.

where $0 < \mu < 1$ is a parameter of the simulation.

The theoretical properties of these dynamics are the subject of specific researches (Deffuant, et al. 2000).

3.3 Generation of the farm population

We generated 118 farms in the model with the help of Dr Skerratt. The difference with the 150 farms estimated by the administration comes probably from the fact that a part of the region is less known by the expert.

Among these 118 farms, there are two possibilities : either the farmer has been interviewed and we have relevant information about the farm, or the farmer has not been interviewed and we only have partial information from secondary data (localisation, type of farming system, approximate size).

When we have only partial information about the farm F, this farm F is associated (by the expert) to an interviewed farm F_p, which seems the most similar. The unknown variables of F are completed by those of F_p, to which a random noise is added (two values of noise have been tested : 20% and 40 %).

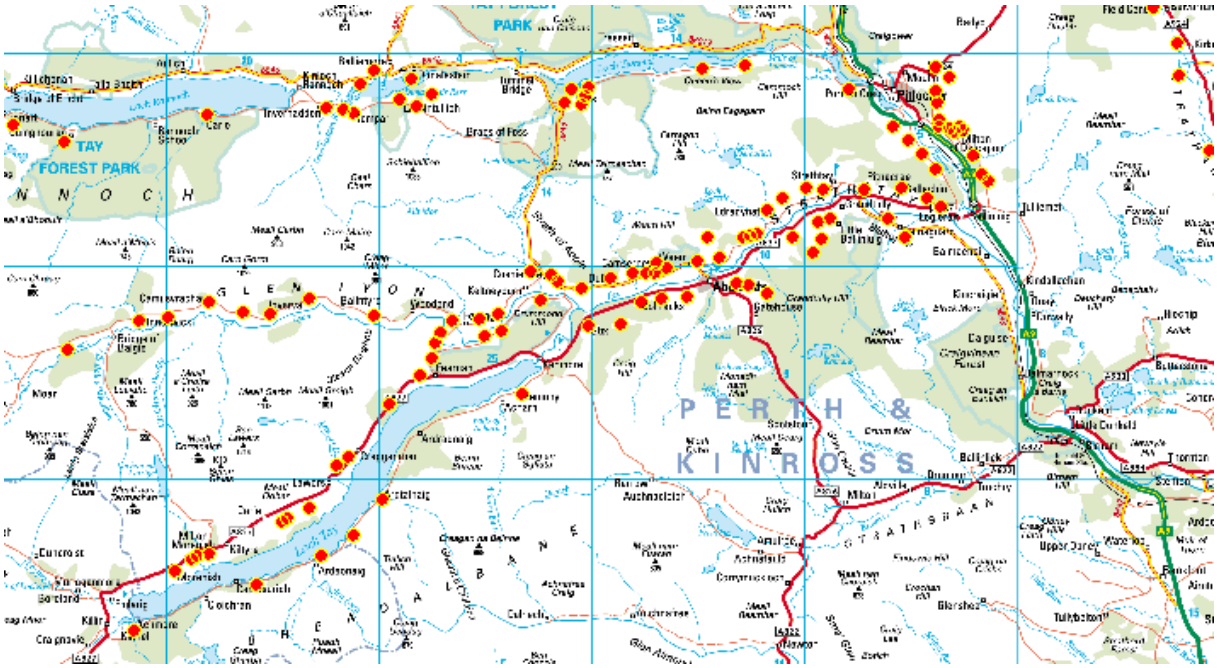

Figure 2. Generation Of The Farm Population Of Breadalbane ESA. Each Dot Represents A Farm.

The values of the motivations are chosen at random from the values of motivations of the interviewed farms. The distributions of these motivations are given in **figure 3** :

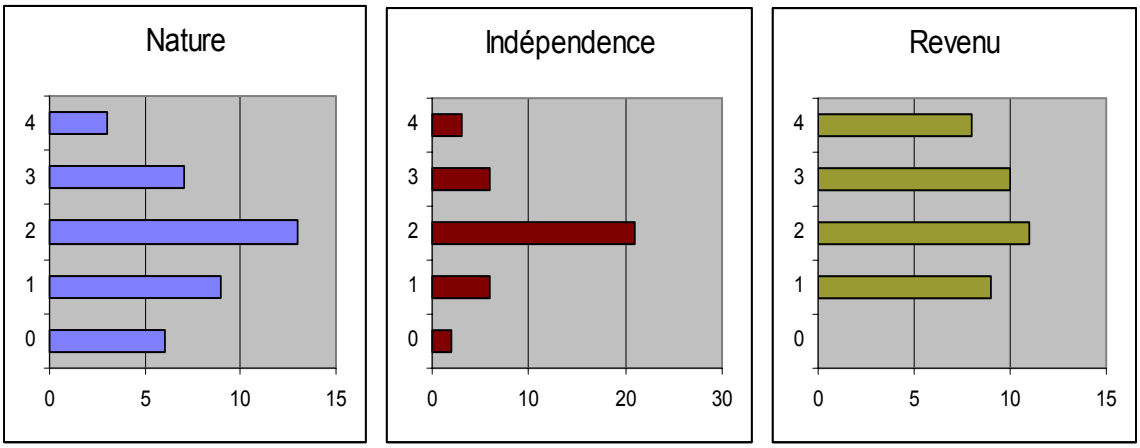

Figure 3. Histograms Of Motivations For Interviewed Farms.

Social networks

Each farmer interacts with other farmers and institutions. The set of farmers and institutions with whom he has a regular link are called his social network.

The link to institutions is given by a probability function which takes as input the farm description and the farmer's motivations. It is estimated from interviews of the interviewed institutions and farmers.

To define the associates of farmer *F*, we consider a generalised distance $d_g(F,F')$ between farmers *F* and *F'* which takes into account vectors **v** and **m** of each farmer.

$$d_g(F,F') = d(F,F') + \alpha.|a'-a| + \beta|s'-s| + \gamma|t'-t| \quad (2)$$

Where $d(F,F')$ is the geographic distance between *F* and *F'*, *a* and *a'* the ages of farmers *F* and *F'*, *s* and *s'* the sizes of the farms, and *t* and *t'* and the types of farming systems. We assume that when farmers have common points (similar age, similar farm, and living not far from each other), then they have more chance to be connected. Therefore, the probability of a link between two farmers is modelled as a decreasing function of $d_g(F,F')$:

$$p(F,F') = \exp(-d_g(F,F')) \quad (3)$$

We have data about the average number of links among farmers (4.8 links). The procedure is then as follows : We draw links within the population with probability *p* until we get the expected average number of links within the global population. **Figure 4** shows an example of result.

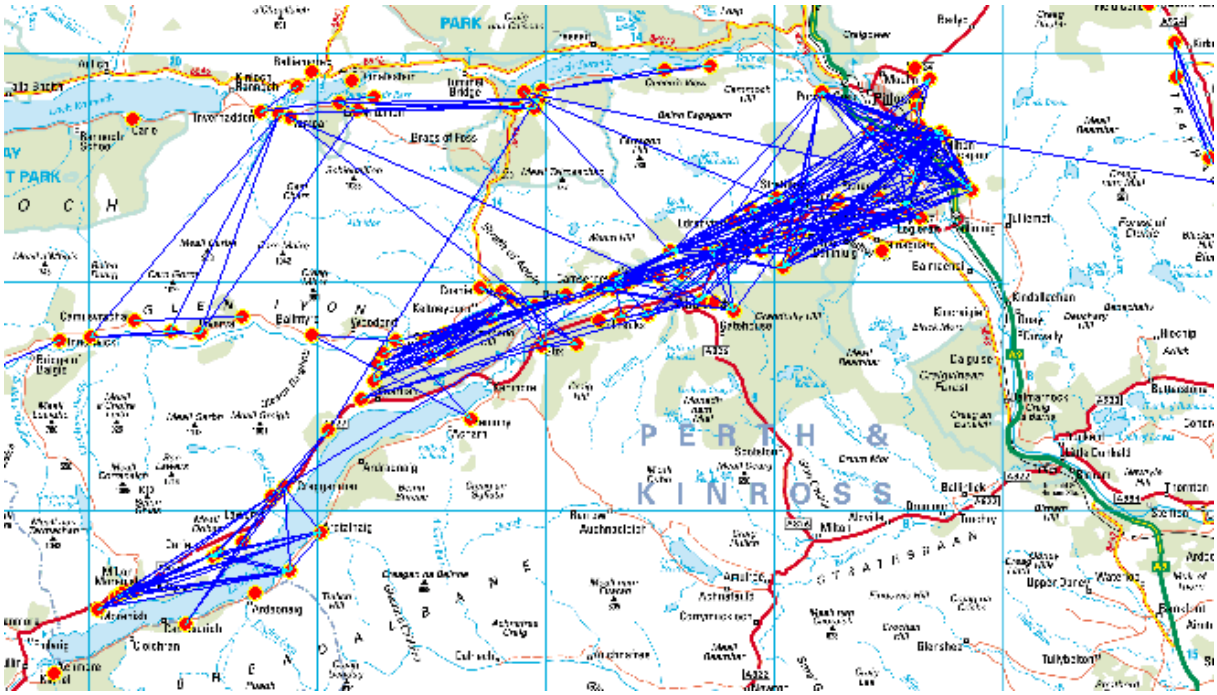

Figure 4. Example Of Social Networks Generated In The Population. It Appears That The Global Structure Of The Networks Remains Similar For Different Trials.

A frequency of interaction is associated to the social link. This frequency is also derived from the same function *d*.

An ongoing work is in progress to calibrate this function on past studies of farmer social networks, and on new data collected specifically for the project.

The social networks derived from this function can be represented as a square matrix of interaction frequencies (f_{ij}):

	F_1	F_2		F_N
F_1		f_{12}		f_{1N}
F_2	f_{21}			
F_N			f_{2N}	

3.4 Institutions

The actions of the institutions are considered as message broadcasting with different media : letters, meetings, visits to farms. The main difficulty is to translate the knowledge we have about these actions into messages on the impacts and the uncertainties. We considered only two institutions in a first version of the model : the press and SAC.

Press

The first articles in the press comprised information regarding the content of the measure and its uncertainties. We chose to translate this information into a general interpretation of the farmers (based on the interviews) :

- A positive anticipation on the revenue, with an important uncertainty that could lead to negative anticipation in the most pessimistic case.
- A negative anticipation on the independence of decision and producer identity, with a high uncertainty, but leaving the value negative, even in the most optimistic case.
- A positive anticipation on the impact on the environment, but with a high uncertainty, leading to negative anticipations in the most pessimistic case.

The values of anticipations and uncertainties are parameters of the simulation that have to be tested.

These messages have been repeated several times in the autumn 1986. In the simulation, the same message is repeated 4 times.

SAC

SAC is the most central institutional actor. We distinguish several actions :

A reassuring message to selected farmers

The first action is to send a message mainly about independence to a selected set of farmers. This message is translated in the simulation as :

- A positive anticipation on the revenue, with a lower uncertainty than the messages of the press
- A neutral anticipation on independence, with a lower uncertainty than the messages of the press
- No message about the environment.

Official launch meeting to present the measure

During its participation in the meeting of March 1987, we consider that SAC broadcasts the same message to a larger audience.

Visits and individual impact calculation

Finally, SAC establishes the ecological diagnosis in a first visit of the interested farms, and then negotiates with the farmer the final plan in a second visit. In the simulation, these two visits are merged. The important point is that these two visits give the farmer a much clearer view of his commitments and his gains.

We developed a calculation of the impact on the revenue, which is based on the average length of the walls to rebuilt, the size of areas to be fenced off (relative to the farm size), the levels of payments, and hypotheses on the costs for fencing and building the walls. We consider that there is an uncertainty on this estimation, mainly connected to the uncertainty on the costs.

Other institutions

The only other institution considered at this stage is SERAD which sends a positive message about the environment in the official launch meeting.

4 SIMULATION PROTOCOL AND RESULTS

4.1 Exploration of the unknown parameters

A simulation protocol is designed to explore the dynamic behaviour of the model according to the values of unknown parameters or the influence on random aspects of the model. These unknown parameters or random parts are :

- The random choice of the links in the social network
- The parameter of the average number of links in the social network
- The thresholds defining the different stages of deciison
- The parameter μ of interaction
- The frequencies of interactions in the different phases
- The values of the messages sent by the institutions

We are looking for the sets of parameters which satisfy the general constraints on :

- The participation in the meeting. This participation is calculated by giving a probability of 0.7 to participate to farmers in stage 2a or 2b and of 0.3 to farmers in stage 1.
- The global adoption data in number of application files each year.
- A small percentage of farmers (2%) begin the institutional procedure and do not adopt

Moreover, it is planned to use the individual data on interviewed farms, to check if the story given by the model matches the data collected in phase 2 interviews.

4.2 Preliminary results

The first result obtained is that it is not possible to find a set of parameters that fits the data of participation in the meeting and the data of adoption in time with the simplified institutional scenarios that we defined.

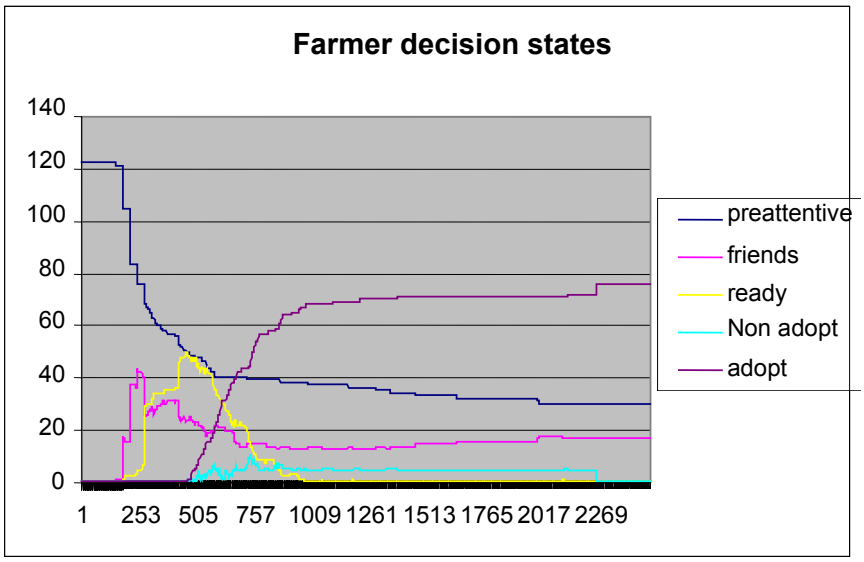

Figure 5. Example Of Simulation Result. The Horizontal Axis Represents Time In Days. The Vertical Axis Represents The Number Of Farmers In The Different Stages Of Decision. The Curve Of Non Adopters Corresponds To The Farmers Who Followed The Procedure And Finally Decided Not To Adopt. The Initial Decrease Of The Number Of Phase 1 Farmers Corresponds To The Messages Of The Press. The Launching Meeting Corresponds To Day 450 (Peak Of The Yellow Curve). The Curve Of Adopters Initially Increases Because Of The Farmers Ready To Do The Official Procedure Just After The Meeting, And Then The Increase Because Of The Discussions Among Farmers.

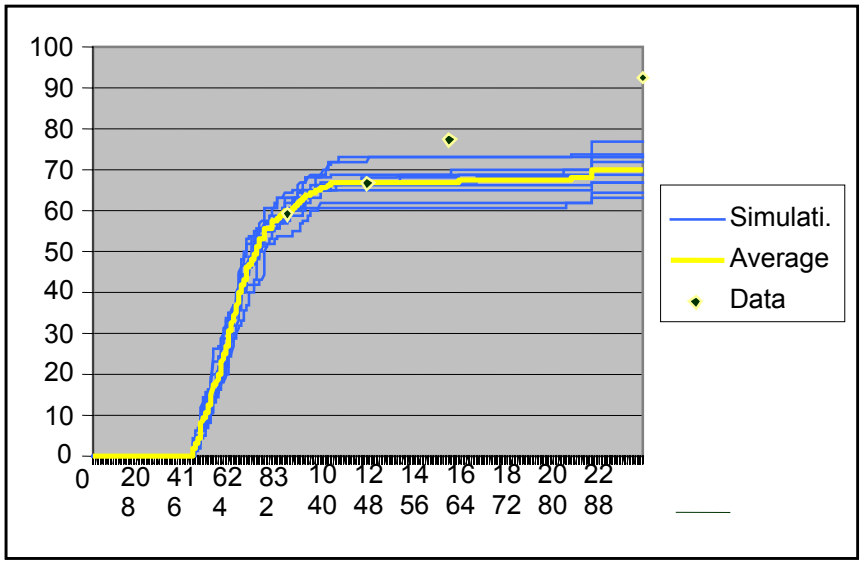

Figure 6. Average Of 10 Simulations Corresponding To Different Social Networks (And Also Different Motivations). The Model Gives A Good Approximation Of The Beginning Of The Process, But Not Of The Final Increase. However, This Final Increase Is Very Probably Due To The Advisor's Specific Action. He Visited The Non Adopters, And Tried To Convince Them. This Action Is Not Represented In The Model, Which Can Explain The Difference Of Results.

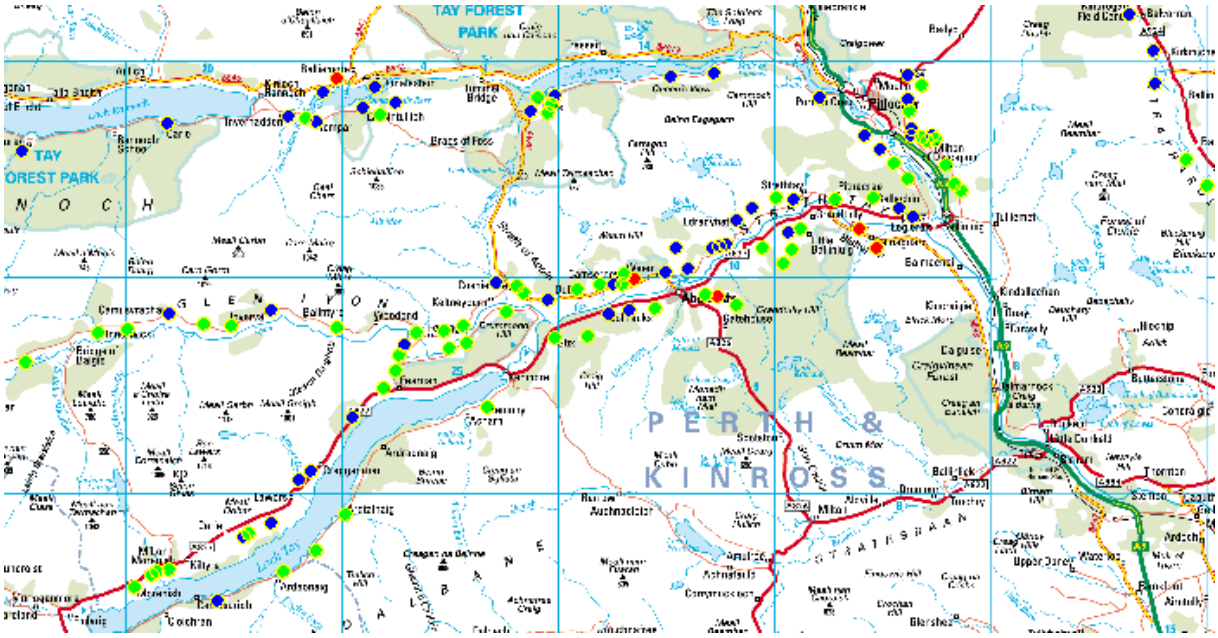

Figure 7. Example Of Simulation. Farms Which Adopted Are In Green. The Geographic Progression Of The Adoptions Follows The Qualitative Description Of The Expert.

The model will have to be also evaluated on the interviewed farms of the population. The idea is to compare the data we have on the decision process from the interviews, and the output of the model.

5 CONCLUSION AND FUTURE WORK

This work is only a first attempt for modelling the implementation of Breadalbane Scheme. However the preliminary results confirm the key role of the advisor in this region. The SAC advisor will be involved in further evaluation of the model, and will give more details about his actions.

This approach will be refined in the following directions :

- Model evaluation for the interviewed cases,
- Elaboration of the model for the second ESA covering the period 92 – 99, and which has been extended to more farmers,
- Introduction of more motivations and impact anticipation in the model, and the evaluation of the corresponding changes,
- Institutional scenarios refinement.

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