PART II

Cases and applications

CHAPTER 3

An agent based model of agri-environmental measure diffusion: What for?

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Abstract

This paper focuses on the agent based model of the diffusion of agri-environmental measures developed in the IMAGES European project (1997 – 2001). We describe the main stages of this model elaboration, showing that it synthesises different modelling points of view. We then illustrate its representative power using a case study in Scotland. Finally, we point out some difficulties in the practical use of such models, particularly as decision supports for policy makers. We advocate a more careful study of the model through systematic experiments, and for the further development of a model of its aggregated dynamics, in order to give more reliable information to policy makers.

3.1 Introduction

Agri-environmental policies propose payments to farmers in exchange for their involvement in more environmentally friendly practices. They are globally defined and financed by the EU, and implemented, with some flexibility, by the member states and the regions. They have diverse goals (reduction of inputs, landscape management, biodiversity conservation, organic farming development), and diverse institutional and legal arrangements. They began in a selected set of experimental regions in 1986, and were generalised all over the EU in 1992. They are an important part of the Common Agricultural Policy reform.

The IMAGES European research project aimed at exploring the potential of an agent-based approach for modelling the diffusion of agri-environmental measures (AEMs), and for helping policy makers to define new ones. We expected that the higher flexibility of agent based models would provide wider possibilities to represent the adoption process. Indeed, previous studies showed that the success or failure of these measures cannot be totally explained by economic factors. It seems that farmers also take into account social and identity related aspects when they decide to adopt/not adopt an agri-environmental measure. The project brought together specialists of agri-environment, rural sociology and modellers from France, Italy and the UK (about 20 people) who collaborated over a period of 3 years. The project involved data collection (interviews with farmers and institutional actors, accounting and demographic data) in 8 case study areas, and a complex process of model elaboration. Different descriptions of the final general model are already published. In (Deffuant et al. 2002) we presented the diffusion of organic farming in the French Allier département. We also recently proposed a study of some properties of the general model (Deffuant et al. 2005).

The objective of this paper is to propose a critical reflection of the agent-based model we developed, using a particular case study as an example: Breadalbane Environmentally Sensitive Area (ESA), in Scotland, UK. In Breadalbane ESA, a specific measure was implemented in order to conserve the biodiversity and maintain the landscape. To adopt the measure, farmers had to sign a contract, negotiated with the advisor, in which they committed to undergo a set of actions in favour of the biodiversity (for instance fencing off some sensitive zones of their fields), or the landscape (for instance repairing the traditional stone walls). Two schemes were implemented: one from 1986 to 1992 (ESA1), the other from 1992 to 1999 (ESA2). The scheme was extended to more farms in ESA2. This case is particularly interesting, because when the model is calibrated on the first period, it can be tested on the second one.

We describe how we used different sources of data to define different parts of the model, and some explorations we made. Actually these explorations are only preliminary, and we use them to reflect on the utility of agent-based models. It is not clear whether our model can be used as a decision support for policy makers, and we argue that this is probably not the most productive use of ABM. We propose instead to use ABMs to explore the potential complexity generated by interactions, and to offer extensive possibilities to experiment in developing theories and analytical models of this complexity. Therefore, we shall advocate a double modelling approach, in which the ABM is an intermediate step, and its behaviour must be captured in a better understood (more aggregated) model.

The paper is organised as follows: first, we present the modelling process and outline the main features of the general model of innovation diffusion proposed in Deffuant et al. (2005). Then, we describe how we applied it to the Breadalbane ESA case study, and we give some explorations of the model. Finally, in the discussion, we point out the limits of this study, and draw together some perspectives on the use of ABMs.

3.2 Modelling process

3.2.1 The agent based model as a synthesis between different views

At the beginning of the project, AEMs appeared so diverse in their goals and implementation that we did not manage to elaborate directly a model representing the whole problem. Instead, the teams explored several modelling approaches in parallel, tackling different facets. The first global model we proposed is therefore a synthesis of these approaches. We now briefly mention these first attempts, which help to understand how an agent based model helps to articulate different views.

- The threshold model of innovation diffusion (Granovetter 1978, Valente 1995, Galam 1997) was a first evident source of inspiration for tackling our problem, and some of the modellers explored this track (Weisbuch and Boudgema 1999). In this model, the behaviour is defined by a boolean variable (to adopt / not to adopt the AEM), and it depends on the sum of an intrinsic payoff and the proportion of neighbours who already adopted (a given proportion of the population are early adopters). The intrinsic payoff was interpreted as an economic reward for adoption of the measure. This model classically shows a tendency to lead either to a global adoption in the whole population, or to almost no diffusion of the AEM at all.
- In parallel, other modellers explored the behaviour of a different type of simple agents (Chattoe and Gilbert 1998). Each agent was defined by a continuous variable called “bias”, which represented its general inclination to consider an AEM. When this variable reached a threshold, the agent made a calculation of the economic benefit of adoption. If this benefit was positive, then the agent adopted the EAM. The agents influenced each other’s bias with a simple averaging mechanism. This model included some explicit representations of institutions and advisors which transmitted particular biases.
- Some project participants focused more specifically on the details of the farmer’s decision making process, using the KADS methodology for developing knowledge based systems, and to base it on farmer interviews (Bousset 1998). This methodology proposes generic modules for problem solving, diagnosis, and planning. In such an approach, the typical sequence of farmer’s reasoning involves operations such as diagnosis, planning, and evaluation of solutions.
- Finally, the last direction was a multi-criteria model of a farmer’s decision. The idea is to define a set of criteria which are important to farmers in evaluating their decision, and then to evaluate the expected outcome of the decision for each criterion. The aggregation of the values for each criterion multiplied by the corresponding weight gives a global assessment of the decision.

During the first year of the project, the paths of work appeared too strongly disconnected to envisage a synthesis in the form of a single model integrating the different levels. The main difficulty of the synthesis was the gap between the standard innovation diffusion models, and the initial models of farmer reasoning based on the analysis of the interviews. Moreover, the models of innovation diffusion seemed very abstract and too simplistic to the agri-environment specialists. They had the feeling that these models did not manage to capture the richness and complexity they found on the ground. In particular, to neglect the direct interactions between the farmers seemed a significant over-simplification. Moreover, the decision process in this model is sudden, single, and without any step. The model with biases seemed closer to the observations from the researchers on the ground, although it also seemed very simplistic.

3.2.2 Synthesis: Dynamics of discussions and multi-criteria decision

A possibility of synthesis arose with the use of a multi-criteria representation of the farmer's decision. This approach could be interpreted as a simplification of the knowledge-based models. The only action considered in this approach is AEM adoption, with the anticipated result of adoption being evaluated using a set of criteria. Each criterion has a weight in the decision. The decision depends on the aggregated value of the weighted criteria. This approach seemed adaptable to both the farmer questionnaire analysis and to the global model of innovation diffusion. Moreover, the model was also simple enough to be represented in large populations, and opened up the possibility for a new way of modelling the interactions: modelling the messages (farmer to farmer) about the evaluation of the AEM, related to the set of criteria.

The choice of a multi-criteria framework to represent the decision is thus the key for the synthesis. It led to the second phase of the project, in which a convergence in the elaboration and testing of a single global approach took place.

The engine of this model comprised advisory institutions sending messages to farmers, who then forwarded these messages to their neighbours. We defined the rule of this message-forwarding such that the tendency to send messages to neighbours decreased when no new message was sent by advisory institutions. The messages included the change of value of different criteria (expected impact) if the farmer adopted, and the associated uncertainties. When a farmer receives a message, the impact and uncertainty he expects are modified with a rule which implements quite general hypotheses in psychology: people tend to neglect the expected impacts which are too far from theirs, and the more certain they are the more difficult it is to influence them (Hegselmann & Krause 2002, Deffuant et al. 2000). These dynamics were extensively studied later on (Deffuant et al. 2002). We identified "computable" criteria, such as economic profit, which can be evaluated through computations with the right expertise. When computed, these criteria are not modified during the interactions.

At each time step, farmers receive messages from advisory institutions and from farmers in their social network, and these modify the values of the farmer's criteria. Then, we compute the "interest state" of farmers, by comparing the aggregation of their criteria and uncertainty in relation to some thresholds. The "interest states" trigger the actions of the farmers (such as going to a meeting, asking for an advisory visit, and adopting the AEM).

The agri-environment specialists within the project team developed a method for the evaluation of these criteria for the interviewed farmers (Dobremez et al. 1999). Table 1 shows the set of criteria considered by the farmers in the UK case studies.

The table was very similar in France and Italy. Agri-environment experts clustered the criteria into three broader categories: individual and economic (farm & economic); social; and environmental.

The output of this procedure is a value attributed for each interviewed farmer and for each criterion. Different variants for the selection of the questions and the attribution of their values were proposed within the team.

Farm & economic	Social	Environmental
Increase level of income	Preserve independence of decision making	Preserve nature
Increase security of income	Get external assessment	Maintain / improve landscape quality
Increase technical mastery	Increase/maintain family patrimony	
Increase flexibility of the farming system	Keep producer identity	
Reducing workload		

Table 3.1: Set of criteria used in the UK case studies

The first model of the social network was based on social distance: the higher this distance, the lower the probability to have a link. This social distance involved the geographic distance, the dissimilarity of farming systems, and the age difference between farmers. It implied identifying 3 parameters corresponding to the weights of these different components, and choosing a particular probability function that decreases with the distance (e.g. inverse quadratic, or negative exponential).

The choice of the multi-criteria representation of the decision and of the type of social network led to the framework for the phase 2 farmer questionnaire and data collection. In particular, the evaluation of each criterion by the farmers, and how this evolved over time, were important data for the model.

We implemented this model and made a set of simulations, trying to fit the different parameters to the data we had in the different case studies, and to interpret the results of adoption. We presented this work at conferences, as well as to the project steering committees comprising potential users of the research (policy makers, and civil servants implementing the policies). This led to some further evolutions of the model.

3.2.3 Final evolutions of the model

The first feed-back from the model led us to simplify it significantly, because many of its parameters were very difficult (almost impossible) to calibrate. But we also added an important part which was missing in the first prototype: information transmission.

The importance of this part was revealed by a closer analysis of the first farmer questionnaire. To compute some criteria, agents need to have access to an objective description of the measure (for instance, conditions and amounts of subsidy, required skills, …). We call this objective description "information". The main subsequent developments in the model are now listed.

3.2.4 Limitation to personal and social criteria

We limited the model to the two criteria of classic innovation diffusion, that is, the personal and social payoffs expected from adoption, rather than using all the criteria that were initially considered. In fact, we considered on the one hand that personal payoffs are equivalent to the aggregated set of criteria dedicated to "farm and economic" and, on the other hand, that social payoffs can be assimilated to "social" and "environment" sets of criteria. Therefore, we finally consider an individual criterion (personal payoff) which is computable and a social criterion which is evaluated during the farmers' interactions. As we previously said, each criterion has a value and an uncertainty.

The reasons for this simplification are:

- For each criterion, we have to postulate the distribution of initial values of the expectation associated with this criterion, within the population. If we consider the uncertainty distribution, this leads to four parameters for each criterion. The first tests on the prototype model showed that the choice of these parameters was not easy. The results of the research for statistical links between these values and the technico-economic features of the farms were not reliable enough to define such distributions with good confidence.
- In addition, the method used to evaluate the criteria did not take into account their respective strength in a decision, which was necessary for the model.

3.2.5 Modification of the social network definition

The criticism of the prototype and the analysis of the phase 2 questionnaire data led to a simplification of the social network definition, because the parameters of the social distance were very difficult to evaluate. The principle of the new model was to separate the social network into three types of links:

- Neighbourhood links, which are selected with a given probability among all links at a distance lower than a threshold,
- The professional links, which are selected with a given probability among similar farms belonging to the same sub-region,
- Random links, which can be at any distance and are selected with a given probability.

The generating algorithm for this network was adapted from those proposed by Watts (1999). It requires four parameters which were easier to evaluate from the data of phase questionnaires (see 3.2.1. for details).

3.2.6 Information transmission and criterion computation by individual farmers

For the model, and based on the case study findings, we proposed that advisory institutions and farmers transmit information about the proposed AEM (such as specifications, corresponding costs, and techniques). This is simplified drastically in the model by considering that the farmer has access to "information" which is either true or false; it is true when he/she has enough information to perform the individual criterion computation, and false otherwise.

When the farmer is uncertain or interested, if he/she has the relevant information, then he/she automatically performs an evaluation of his individual criterion value and uncertainty. This evaluation takes as inputs: the farm descriptors (size, farming system, different productions), the specification of the measure, and some lower and upper expectations of different impacts (for instance yield decrease due to input reduction, prices increase in the case of organic products, increase of workload in work intensive measures). The evaluation gives as an output the mean economic payoff and its associated uncertainty. In general, the elaboration of this model was difficult, and led to different developments depending on the measure being considered.

We distinguish between the evaluation that farmers can do by themselves, and the evaluation they would be able to do with the help of a specialised technician/adviser. We consider that the technician/adviser would bring more information and reduce some uncertainty.

3.2.7 Institutional actors

Advisory institutions are in charge of the delivery of the measure. They are therefore involved in diffusing information and criterion information, and/or in visiting the farms and helping farmers to evaluate the impact of adoption. An institution is characterized by:

- A diffusion network which is a subset of the farm population (that is, "target farmers" likely to be early adopters).
- A diffusion scenario comprising dated messages which include criterion, and related uncertainty and/or information; for each message, it specifies the probability that this message reaches farmers who are: not interested, uncertain or interested, visited or who adopted. This allows us to simulate the organisation of meetings.
- In some cases, an advisor who helps the farmer to calculate the economic impact of adoption (as in Breadalbane). An event which simulates the beginning of the advisor's visits in the geographical area triggers the possibility for farmers to request the institution for a farm visit. The visits are then progressively performed, according to the number of farms per day the institutional advisor can visit farms.

It is important to remember that the institutions trigger the dynamics of discussions among the farmers: those who receive their messages then send them to their neighbours, in a progressively decreasing cascade of interactions.

3.2.8 Simplification of the definition of interest stages and farmers' associated actions

In the final model, we defined only three "interest states": not interested, uncertain and interested. These are defined by comparing the aggregated expectations (using the social and economic criteria) plus or minus the uncertainty up to a threshold. Only one threshold is used to define the three states (which limits the number of parameters) [1].

The definition of the actions is similar to the one of the prototype, except that the farmer must be interested in order to be involved in the institutional procedure (often comprising the visit of an advisor). He/she must remain interested for a given number of time-periods and have completed the full administrative procedure to actually adopt.

3.3 Example of Breadalbane ESA

During the project, the model was adapted to several particular case studies. We now illustrate its application through one particular example.

3.3.1 The AEM and its implementation

Funded activities

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 version of the AEM (ESA1) was launched during the period 1987 – 1992, and a second one (ESA2) during the period 1992 – 1999 [2].

The measure consisted in several types of activities which focused on landscape and biodiversity:

- A livestock management commitment to AEM requirements, which distinguished between the quality of land (inbye or rough grazing), through an annual payment proportional to the contracted area of the farm;
- Rebuilding the traditional walls, with payment proportional to the length of walls to be rebuilt;
- Fencing off ecologically rich parts of the land, in order to maintain biodiversity, with payment proportional to the length of fences required; and
- Bracken control, with payment proportional to the treated areas.

[1] Three states are defined with a single threshold because two variables are considered: the value and the uncertainty of the criterion (see Deffuant et al.2002a, 2005) for details.

[2] ESA1 was evaluated during its lifetime by the Scottish Agricultural College (SAC), and changes were implemented at the end of 1991 for the new scheme launched in 1992. The main changes comprised an extension of the ESA boundary to cover a larger area (ESA1 comprised 120,000 hectares, ESA2 comprised 200,000 hectares), and an increase in levels of payments and range of funded activities.

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

3.3.2 Population of farmers

The population of the case study area is approximately 150 farmers in the territory of ESA1, and approximately 180 for the territory of ESA2, from which 40 were interviewed in a first phase, and 20 interviewed again in a second phase. The average size of the farms is around 650 ha, with a minimum of 30 ha and a maximum of 6300 ha.

3.3.3 Main steps of the implementation of the ESA.

For both ESA1 (1987-1992) and ESA2 (1992-1999), the organisations formally involved in the implementation were:

- The Scottish Agricultural College (SAC), which was in charge of the promotion of the scheme, and for the drawing up of ESA farm plans / contracts.
- The Scottish Executive Rural Affairs Department (SERAD), which was in charge of the approval of the applications.

For ESA2 only, the Farming and Wildlife Advisory Group (FWAG) was responsible for producing the ecological component of the farm habitat survey, and for supplying this to SAC who then put together the farm activities plan.

In addition, in both ESA1 & ESA2, other actors or organisations such as the media and the landlords were informally involved in this implementation. Firstly, « the media » is defined as including the agricultural press, agricultural television programmes, and agricultural radio broadcasts. Messages (both information and criteria) concerning the ESA were channelled through these sources during the lifetime of both ESA schemes. After an analysis of the interviews with institutional actors and farmers, we consider that the main steps of the ESA implementation process to be:

- Autumn 1986: the media broadcasts first descriptions of the scheme. The main principles of ESA1 have been decided, but many uncertainties remain (for example, concerning precise payments and exact ESA1 boundaries);
- End of 1986: SAC contacts a subset of farmers (10) to begin the promotion of ESA1. The message is that the ESA is financially beneficial, good for the environment, and positive for farmers' image as «custodians of the environment ».
- March 1987: Official meeting for the promotion of the scheme instigated by SERAD and SAC. They give more explanations about the ESA scheme. The message of SAC is globally the same as for the farmer subset. SERAD's message is that there will be a negative impact on farmers' independence in decision-making, and that the ESA will be positive for nature. 65% of the farmers participated in this meeting.
- From March 1987 to end 1992: The interested farmers must contact SAC. The SAC advisor 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 agricultural business priorities alongside 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, although it can be much longer (more than one year) for some farmers. Only a small percentage (4%) of farmers who began this process did not finally adopt.

- Spring 1992: Official meeting for the promotion of the ESA2 scheme, instigated by SERAD and SAC. They give more explanations about the ESA scheme. The messages of SAC and SERAD are globally the same as for ESA1. 60% of the farmers participated in this meeting.
- From Spring 1992 to the end of 1999: Farmers interested in ESA2 must contact SAC or FWAG. The FWAG advisor comes to visit the farm and establishes an ecological and landscape diagnosis, which is then sent to the farmer and to SAC; 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 by SAC, taking into account agricultural business priorities alongside 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 6 months, although it can be much longer (more than one year) for some farmers. Only a small percentage (4%) of farmers who began this process did not finally adopt.

- Summer & Autumn of 1999: the SAC advisor targets some remaining non-adopters (farmers who have either not adopted the original ESA1, and/or ESA2), first with a letter and then with a phone call and visit, informing them the ESA is due to close at the end of 1999, and they will therefore lose their opportunity to join the ESA. The message is, once again, positive for income and environment.

3.3.4 Adoption data

The adoption data month by month (communicated by SAC) are shown on figure 3.1.

3.3.5 The model

We applied the general model to the particular case of Breadalbane. This allowed us to:

- Design a population of farmers with social networks, initial social criterion values and descriptors that allow us to compute the individual benefit of adoption;
- Define the institutional actions diffusing messages about the measure, as well as the institutional procedure of adoption.

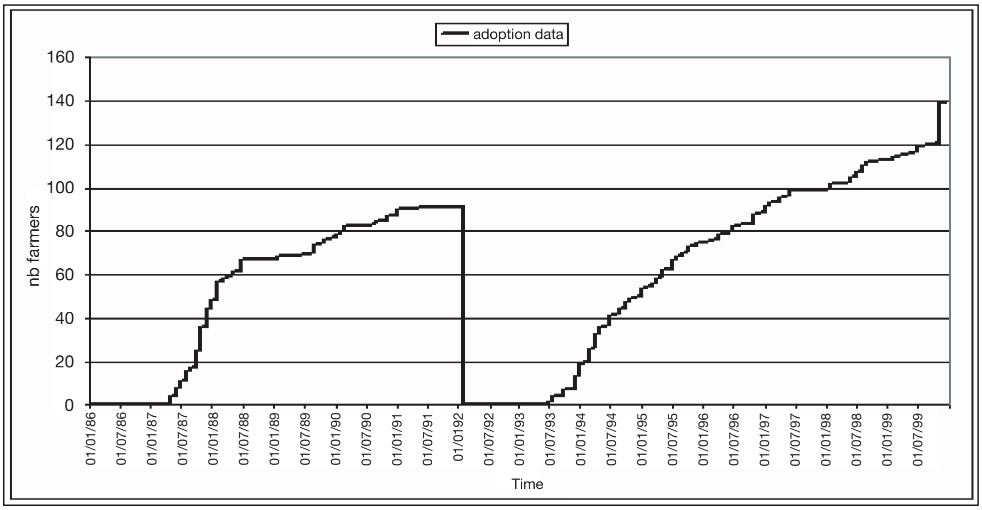

Figure 9: Adoption data for ESA1 and ESA2 (source : SAC). The adoption increases very rapidly right after the meeting in ESA1. Then there is a small plateau, and a growth again. For ESA2, the growth is more regular during the whole period, except at the end, where we can see a sharp set of adoptions.

3.3.6 Population design

Using secondary data sources, it was possible, for each farm within the ESA (where ESA1 = 127 farms, and ESA2 = a total of 160 farms), to collate data relating to: farming system (sheep; sheep & cattle; sheep, cattle & arable; cattle & arable); farm size (hectares); and tenureship (owned, rented, mixed). These three characteristics were selected, since other research indicates that they can be significant in terms of the types of decisions taken by the farmer, and in terms of probable links between farmers within their social networks (Cezar *et al*, 1999; Gasson, 1971 & 1988; Skerratt, 1998, 1994a & 1994b). Data did not allow us to rebuild exactly the population: approximately 23 farmers for ESA1 and 20 farmers for ESA2 were lacking.

The social network comprises three categories of links: geographical neighbourhood, professional and random links. Four parameters have to be valuated: the mean neighbourhood's connectivity and the maximum distance for neighbourhood links; the mean professional connectivity; the mean random connectivity.

Very few data are available on the way one farmer is linked to others. From data analysis for respondents of the second farm questionnaire, we noticed that the average number of links is never higher than 5. This gives us a rough approximation of mean values but these parameter values should be the object of further investigation. The maximum distance for neighbourhood links, and the professional links, was determined by the agri-environment specialist from her knowledge about the questionnaire respondents and the data analysis from the second survey. The professional networks are links which correspond to potential professional encounters in markets and at professional meetings.

One practical problem in calculating the neighbourhood networks is to evaluate the communication distance between two farms. This communication distance can be very different from the Euclidian distance between the farms, because it takes into account the natural obstacles, and the topology of the roads. Ideally, the communication distance should be computed through a GIS in which all the information about the obstacles, and types of road, is stored. Since we did not have this information, we proposed a method which allowed us to approximate the communication distance. This method is based on the concept of "direct neighbours" (Deffuant et al., 2001, p. 157). Figure 3.2 gives an example of the final generation of a network, including the three types of links: neighbourhood, professional and random.

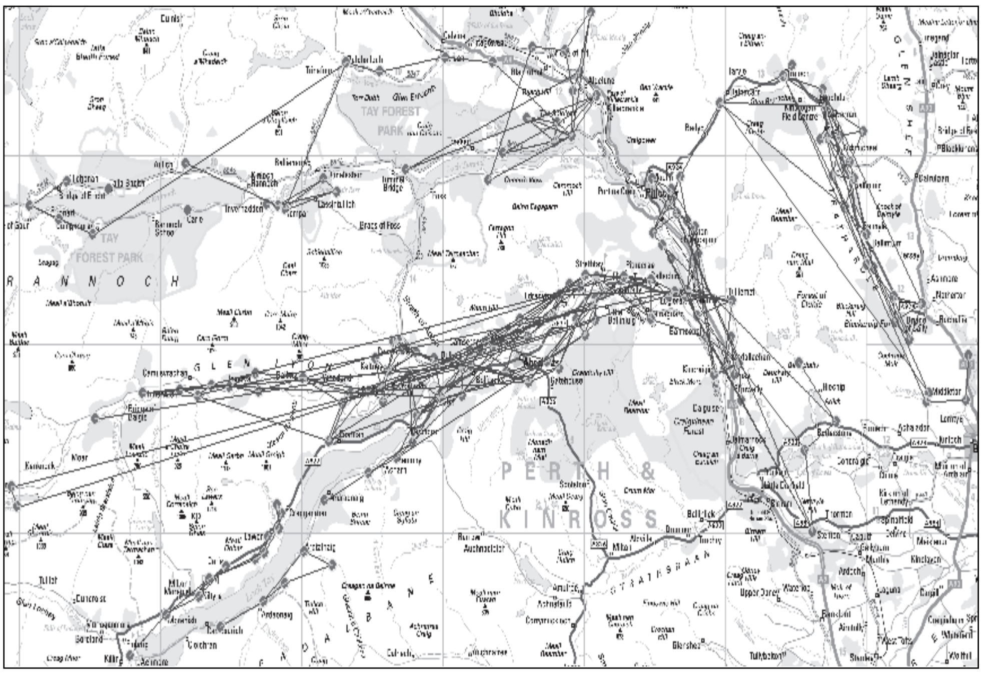

Figure 3.2. Example of social network generation, with 3.5 neighbour links, 1 professional link and 0.3 random links on average per farmer. The number of totally isolated farmers is very low.

In order to initialise the value of the social criterion, we used the data from the first farmer questionnaire which indicated that farmers generally had a favourable interpretation and experience of the measure. Unfortunately, the linear correlation between these values and socio-economic indicators of farms was not significant enough. Therefore, we drew the social criterion value from a Normal distribution. The mean and standard deviation of this distribution are parameters of the model, and we had to evaluate their influence on the global behaviour of the model through systematic explorations and sensitivity analysis.

3.3.7 Financial impact

For each farm, we evaluated the financial benefit of adoption and its associated uncertainty, as a function of the descriptors of the farm. These values must be estimated both before the development of the farm plan (individual evaluation), and after this. Of course, without the actual farm plan, the evaluation includes much higher uncertainty than with the farm plan.

We mainly used the evaluation by Lilwall et al. (1990), which brought us important data about:

- The economic impact of the measure on the farms, and
- The breakdown of the various conservation activities and their relative cost.

We also used different documents which outlined specification of the measure, and an example of a 'standardised' farm plan which had been communicated to the farmers in the information meetings.

The global results of mean financial impact as a percentage of the farm gross margin for the whole population are positive for both ESA1 and ESA2. Moreover, it appears that ESA2 is financially more beneficial than ESA1 for a significant number of farmers. We also evaluated the uncertainties, which vary between 10 to 30%.

3.3.8 Institutional actions

In this part of the model, we describe all events concerning the diffusion of the information relating to the measure, as well as the characteristics of the institutions in charge. Information and criteria are diffused by sending "institutional" messages to a part of the population. These messages trigger discussions among farmers.

From data analysis and expert knowledge (see 3.1), we simplify the institutional scenario by considering only one global actor implementing the measure. This actor represents SAC and the other organisations which participated in the implementation of the measure and in the meetings (that is, SAC, SERAD and FWAG). Further, this global actor is an advisor who must visit a farmer two times before the farmer can adopt.

We considered a basic scenario comprising the most important actions of the institution (see 3.1.3), which can be outlined as follows: (i) an action of communication to a small set of leader farmers at the very beginning of ESA1, a few months before the information meeting; then (ii) an information meeting takes place in the beginning of 1987; (iii) the farm visits begin just after the information meeting; (iv) an information meeting takes place in the end of 1992 for ESA2; and finally (v) the farm visits begin in 1993.

3.3.9 Example of results

We performed a partial exploration of the influence of several variables on the model, and we compared the results with the actual curves of adoption. For more details see Deffuant et al. (2001).

Figure 3.3 shows the evolution of the number of interested, uncertain, not interested, visited and adopting farmers over time for one example of good fitting.

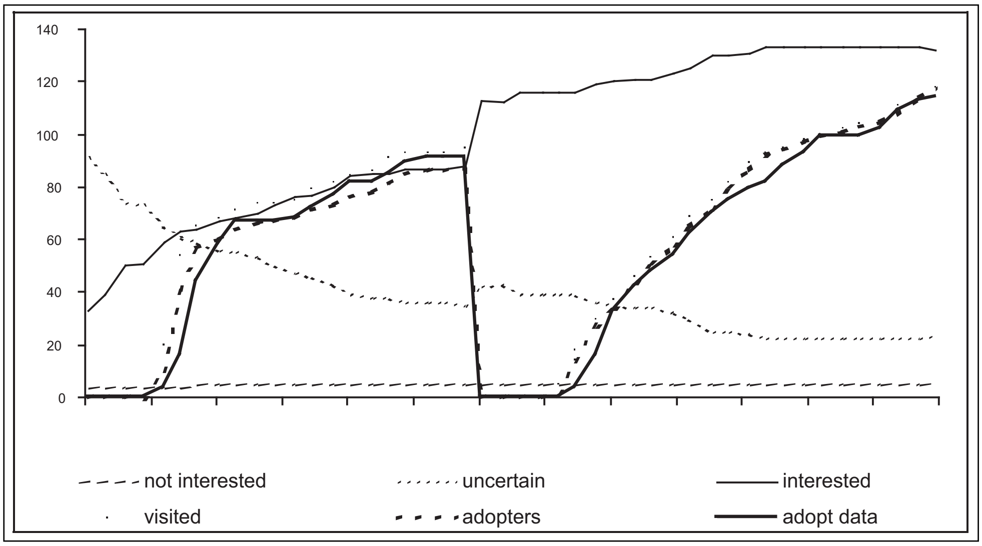

Figure 3.3 Example of good fitting of the curves of adoption (see Figure 9 for comparison). The sharp change in the number of interested farmers in January 1992 corresponds to the addition of farmers who are eligible for ESA2, and who are not counted in the first part of the curve. The global error in percentage of adopters is less than 10%.

One can notice that on this example, the number of non interested farmers at the beginning is very low: the majority is uncertain, and there is a minority of a priori interested. Then the number of interested is constantly growing until 1992 where there is a sharp increase, due to the addition of newly eligible farmers for ESA2, who were already interested because of their discussions in their network. One can see that the number of interested farmers in the second ESA is high at the beginning. The relatively slow progress of the adoption curve comes from the necessary delays of the visits and farm plan development, and to the necessary delay of five years after the first adoption (because the first contract of 5 years must be finished to begin the second one).

The situation is very similar to a case where the model is calibrated on a first phase, ESA1, and then tested on the second, ESA2. An interesting point about the simulations is that the parameters leading to the best fitting of the ESA1 adoption data are also the ones leading to the best fitting of the ESA2 adoption data. This is a good sign about the predictive capacities of the model. However, some caveats must be set alongside this optimistic impression: there is a parameter ruling the rhythm of the visits, which is responsible for the slope of the curve in the ESA2 period. This parameter is fixed according to approximate information about the number of farmers' files treated in normal conditions, but it means that the second part of the curve is not totally determined by the first part.

3.4 Discussion

3.4.1 Analysis of the achievements and difficulties

First, let us consider the positive aspects. In our view, the main one is the synthesising potential of the model. It allowed us to gather into a single coherent whole the different views of the problem. In doing this, we managed to articulate an elaborated farmer decision process, the computation of complex economic anticipations, social influences and information diffusion, and various institutional actions (meetings, message broadcast, and visits to farms). The model of a social network presented good qualitative fitting, in the view of the agri-environment specialists. Moreover, the model was compatible with very different case studies, which illustrates its representative power. Therefore, the model provided a set of concepts and representations of the dynamics of AEMs implementation and diffusion, which are more precise and explicit than in descriptive discourses.

If we consider the example of application that we briefly described for Breadalbane ESA, in some respects the results we presented seem satisfactory. With some parameter values, it seems that the model has some predictive power. When calibrated on ESA1, it yields good results on ESA2. This could lead to optimistic conclusions on the potential of the tool as a decision support system.

However, a more careful analysis leads to more moderate conclusions. Policy makers are interested in the future. Can we guarantee anything about the performance of the model in the future? The answer is clearly no, at least in the current state of the work. The current study of the model did not allow us to understand fully the role of the different parameters, and the robustness of the results for the different values of these parameters. Moreover, when the number of parameters becomes very high compared to the data to predict (the evolution of adoption), one can always expect to find some parameter values which will fit the data. The 'predictive credit' we can allocate to these parameter values is very difficult. This is particularly true of the parameters to initialise the distribution of social criterion values in the population. This would certainly prevent having any confidence in the model's predictive results for a next scheme. This leads us to question the utility of agent based models.

Of course, the question is not new. It has been put forward by critiques of ABMs for a long time. One answer from a part of the ABM community has been the idea of "companion modelling" (Bousquet et al. 1999, Baretteau et al. 2003). According to this view, the main objective of an ABM is not to predict the evolution of a phenomenon, but rather to stimulate multi-disciplinary interactions, and to facilitate discussions among stakeholders. The model becomes a means for different disciplines looking at the same object to interact and to try to understand each other. This positive effect of modelling was actually experimented many times, in particular in the IMAGES project. However, it restricts ABMs to a pretext of discussion among scientists, or among stakeholders, and tends to avoid some crucial discussions about the modelling methodology.

3.4.2 Using ABMs as experiment sources for building robust theories

We would like to advocate another use for ABMs, which – in contrast - brings questions of modelling methodology to the forefront. In this approach, ABMs are considered as a tool with which to explore the effect of various hypotheses on the interactions between agents (such as targeting by institutional agents, frequency of contact between farmers of a certain type). It is well known now that these interactions can lead to global phenomena which are very difficult to predict from only the knowledge of the individual dynamics and interactions. Therefore, to understand how the micro-dynamics produce macro-effects in such models is often a scientific problem. In this perspective the ABMs become sources of experiments for understanding such micro-macro effects. These are of great interest in the policy arena, particularly given interest in 'territorial' responses to, and impacts of, rural development policies and programmes (Shucksmith, 2004), and as illustrated in the new Rural Development Regulation (2007-2013) with the mainstreaming of locally-led development agendas through the "LEADER approach".

A first possibility is therefore to perform specific experimental designs, which allow us to draw the map of model macro-behaviours in the parameter space. We adopted this approach for exploring the model of social influence and several of its variants (Deffuant 2002, 2006) and a generic model of innovation diffusion, inspired by the model we described in this paper (Deffuant at al. 2005). In the latter case, it allowed us to identify particular effects of the *a priori* social criterion about an innovation, which can dramatically slow down the information diffusion about an innovation. When we tried to use this approach on the models applied to the case studies[3], the dimension of the parameter space was generally too high to get a global picture of the model behaviour with a tractable number of simulations. In this case, we can observe the occurrence and the properties of general patterns on the ABM, according to parameter values. These results can then be compared with the occurrence of patterns in data collected on the phenomenon under consideration (following a "pattern oriented modelling approach", Grimm & Railsback 2005).

This view can modify the methodology of modelling around ABMs even more deeply, since the ultimate goal can become to provide a more synthetic model or theory of the macro dynamics, for instance using differential equations on probability distribution evolutions, in a given state space (following a general approach used in "socio-physics", see Weidlich 2000 for instance). The ABM is then only an intermediate step which allows us to explore the variety of macro-phenomena which are produced by the different micro-dynamics. In this case, although the ABM is not the final goal, it is nevertheless very important, because it allows the scientists to identify some micro-macro phenomena that would be impossible without simulations. This view is already partially advocated in (Dieckmann et al. 2000). The difficulty in this case is to elaborate aggregated models of the global behaviours of ABMs, which are reliable enough approximations, especially when spatial interactions are important.

As a consequence, two main directions of methodological work appear particularly important. The first one refers to the design of simulation experiments, which must be specifically developed in order to provide efficient model explorations, and observe the micro-macro phenomena with good confidence. The second one is about the methods for designing aggregated models, representing the macro-phenomena and patterns (possibly dynamic). Results from both models are compared to identify

[3] Not described in this paper. See (Deffuant et al. 2001) for more details.

similarities and differences. The differences can guide the design of ABM experiments which help to explore the parameter zones where the ABM behaviour is not well represented. This leads to a global approach which can be qualified as “double modelling”: the objective is to design a synthetic model of the relevant complex (i.e. micro-macro) phenomena that the agent-based model enables us then to understand.

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