# Building causal maps of livestock farming systems using a participatory method with dairy farmers

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**Abstract:** To improve sustainability, farmers may want to redesign their livestock farming systems in depth, e.g. convert to organic farming. Assuming that modelling livestock farming systems can support such redesign processes, we devised and tested a modelling methodology in which farmers participated. Fifteen cattle dairy farmers converting or converted to organic farming took part in our programme. The programme first consisted in a series of meetings and surveys with both the local extensionists and the farmers. This first step made it possible to identify a list of relevant topics linked to the converting processes, and to make the farmers feel more engaged in the programme. The following step was made of participatory workshops during which farmers were invited to express their own views about the previously identified topics. Such views were modelled as causal maps the structure of which was defined by the farmers themselves. The maps aimed at representing the operation of the livestock farming systems. Some difficulties of our methodology are discussed, together with its potential uses and interests for both research and development purposes. In each case, the benefits of participation are highlighted.

***Keywords:*** *livestock farming systems, modelling, participation, redesign, support tools, causal mapping*

## Introduction

Livestock farming has recently come under close scrutiny, in response especially to environmental issues (Steinfeld et al., 2006). There is increasing societal pressure for more sustainable livestock practices. In response, stockbreeders may decide to convert their systems to new forms of operation that they judge more sustainable. In this case they are faced with what we can call 'systemic innovation'. 'Systemic innovation' is on the level of practice, i.e. the farm, whereas the same kind of innovation is called 'system innovation' on the regime level in the multi-level perspective (Elzen et al., 2004), by contrast with 'genetic innovation' (e.g. new animal or plant genotypes) or 'technological innovation' (e.g. new tools to calculate animal diets or fertiliser levels) (Meynard et al., 2006). Genetic, technological and system innovations are based on different technological paradigms that have not all been equally successful in influencing agricultural research, which disfavoured system innovation (Vanloqueren and Baret, 2009). However, system and systemic innovations have recently been significantly encouraged, for example by the French National Institute for Agronomic Research (Meynard et al., 2006), and the International Assessment of Agricultural Science and Technology for Development, which has recommended a reorientation of agricultural science and technology towards more holistic approaches, after a four-year process involving over 400 international experts (IAASTD, 2008).

Undertaking systemic innovation by switching to new forms of operation in farming systems requires certain transition processes. In converting to organic farming for instance, such transition processes, the importance of which is often minimised in the literature, would benefit from being addressed in terms of system redesign (Bellon et al., 2007) rather than in terms of simple input substitution (Lamine and Bellon, 2009). A more holistic view of the farming system's operation may serve that purpose (Niggli, 1999). Systemic modelling is a relevant way to take such a holistic view. A 'model' can be broadly defined as a finalised representation of reality (Legay, 1997); it can be either conceptual (i.e. theoretical) or implemented (i.e. software-integrated). In the study of farming systems, modelling has proved an efficient tool to gain an understanding of how the systems operate, identify knowledge gaps, predict evolution, and assist the systems' managers in their decision processes (Malézieux et al., 2002).

A preliminary study based on a literature review of all models of livestock farming systems published from 2000 to 2009 showed that the main current modelling rationales supporting changes in livestock farming did not fully meet the objective of supporting farmers in their redesign processes (Gouttenoire et al., submitted). The study also suggested that implementing participatory modelling projects with farmers could help meet this challenge. The aim would be to build a conceptual model of a livestock farming system that could be structured through farmers' participation.

A participatory project of this type offers two advantages: (i) participation guarantees better use of the companion tools designed jointly with the stakeholders (Newman et al., 2000; Mc Cown, 2002; Woodward et al., 2008; Cerf et al., 2008), and (ii) participation makes it possible to interact with farmers' forms of knowledge (Darré et al., 2004), which may be usefully added to scientific knowledge in addressing specific questions (Campbell and Salagrama, 2001). In particular, the vision of the farm expressed by the farmers themselves may be more directly linked to action and decision.

Very few models of livestock farming systems have been built in a participatory way. Many modelling projects use on-farm surveys or consultation of agricultural experts as research practices to enrich a model the structure of which has been set by scientists. In Vayssières et al. (2007), this kind of actors' participation played an even more important part: the decisional submodel of the whole-farm model GAMEDE was built by combining different methods involving farmers, such as immersion, meetings and visits. However, the model's structure was based on pre-existent scientific concepts: the action model (Sebillotte and Soler, 1990), and an ontology of agricultural production systems (Martin-Clouaire and Rellier, 2000).

To our knowledge, only three published models of livestock farming systems have been truly structured by non-scientist actors' participation. In Van Calker et al. (2007), the objective of the participation was to define a set of indicators of workers' physical health and societal sustainability in dairy farming systems. Experts and stakeholders from the whole society were involved, but farmers did not participate. By contrast, farmers were the main target of the participatory program carried out to build the model of Bosma et al. (2006). This model does not represent the operation of a livestock farming system, but addresses a narrower issue: understanding in what circumstances farmers choose to integrate aquaculture into agriculture in the Mekong Delta. The only model built in a participatory way that seeks to represent the operation of livestock farming systems is that of Madelrieux et al. (2006). This conceptual model sets out to formalise certain system consistencies, e.g. work organisation. However, the actors most closely involved in building the model were not farmers but experts. Hence to our knowledge no conceptual model of the operation of a livestock farming system has yet been built in a participatory way with farmers: to achieve this requires prior methodological research.

Our purpose here is to describe a new modelling methodology we have devised and tested to build conceptual models of the operation of livestock farming systems in a participatory way with farmers. This work is an integral part of a PhD project the aim of which is to answer the following question: 'How can livestock farming systems be modelled to help farmers redesign their whole farming systems?'. The main methodological principles are first described. The successive steps of our methodological route are then presented. Finally, potential uses of the models are discussed, together with the benefits of participation.

## Our main principles

### Farmers as the targeted participants

We set out to build both a methodology and conceptual models that could be further developed into companion tools to be used by farmers, if necessary with their advisors, to help them redesign their livestock farming systems. Two main categories of stakeholders could therefore be defined: farmers and advisors. As the farmers are the main actors and final decision-makers in livestock farming systems, the trade-offs between complexity and simplification in their views of the farming systems may be naturally linked to action and decision. This effect is of importance in designing appropriable support for farmers' strategic thinking. We therefore chose farmers as the targeted participants for the conceptual modelling processes. On the other hand, in our opinion, advisors' participation would be better used for deriving companion tools from the proposed methodology and the conceptual models built with farmers. However, these processes lie outside our present scope.

**Working with farmers already involved in innovative processes**

Redesigning livestock farming systems can be seen as an innovative process for farmers. Following Goulet et al. (2008), we use the word 'innovation' to describe the processes that lead to the creation and adoption of novelties in a given socio-economic setting. This kind of innovation has a strong collective dimension: farmers often benefit from their memberships to different professionnal groups (e.g. cooperative use of agricultural equipment, boards of agricultural organisms) to gain some experience and to valorise it in their own farms (Goulet et al., id.). We chose to involve farmers who had already experienced or who were currently experiencing such innovative processes, as we assumed that such farmers would have already thought about how the consistencies of their farming systems might be modified according to the different ways they could be redesigned, which would facilitate the modelling process. Local dynamics of innovation were therefore sought, in order to find farmers who could usefully participate in our modelling program. A local group of 33 cattle dairy farmers converting or already converted to organic farming in the Pilat region (eastern Massif Central, France) was selected. The conversions were driven by the farmers and supported by a milk plant.

**Modelling in participatory workshops rather than individual interviews**

We chose to do the modelling work in participatory workshops with about five farmers. Individual interviews could have been considered, but we preferred participatory workshops for three reasons. First, as we considered the processes of innovation to be collective, it was more consistent to build the models collectively. Second, we considered that inviting several farmers with different levels of experience in organic farming would motivate them to participate and discuss, which would facilitate the process of formalising the operation of the livestock farming systems. To constitute the groups, rather than striving for heterogeneous groups conducive to more debate, we paid special attention to the participants' eagerness to exchange ideas with the other participants of the group. We assumed that such an eagerness would guarantee promising and respectful discussion. Third, producing a representation that is relevant for a whole group enabled us to make the model more 'generic' than if it had been devised at the individual level. This model is relevant at least at the level of the local professional group (Darré et al., 2004).

**Causal mapping as a modelling tool**

We chose to use cognitive mapping, and specifically causal mapping, to model the operation of the livestock farming systems. A cognitive map is a 'graphic representation of a set of discursive representations made by a subject with regard to an object in the context of a particular interaction. It is the work of a researcher who constructs a graphical representation of a discourse uttered or written by a subject' (Cossette and Audet, 1992). A causal map is a cognitive map based on formalising causal relationships (cause/consequence or means/goal) uttered by one or several subjects.

Causal maps are built using the subjects' natural language (Cossette and Audet, 1992), which prevents researchers from formatting the model according to their own representations, and so makes the participation more meaningful. Conceptual modelling acts as a filter between the users' needs and the development of tools (Juristo and Moreno, 2000). The information entered in a causal map does not have to be reformulated to correspond to any preset categories (e.g. indicators, objects, or management entities). Therefore, as cognitive mapping is a flexible formalising tool, information loss *via* the modelling filter is reduced. Furthermore, as causal maps represent the modelled objet as a set of concepts and causal relationships between concepts, they are useful for systemic analysis, an advantage when more holistic approaches are to be implemented. Finally, because they are based on causal relationships, we consider causal maps as relevant tools to examine different changes and their consequences for livestock farming systems.

In using causal maps, our purpose was not to model the cognitive processes of the actors, but rather to build representations that will be of use for discussing the redesign of a livestock farming system.

An example of a causal map is given in Fig.1.

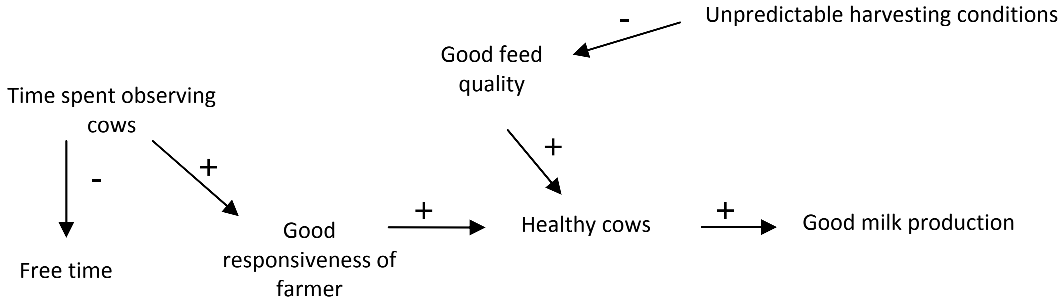


**Figure 1.** Extract of a causal map built with farmers (the whole map contains 178 concepts and 304 links).

### Practical questions as a start to the modelling process

To facilitate discussion between farmers and so help the modelling process, we chose to start the participatory workshops by discussing practical issues that concern the farmers in their redesign situation. This choice also opens the domain of livestock practices, and so prevents overreliance on theory, a sometimes reported drawback of using causal mapping (Girard, 2006). This requires prior individual surveys to identify practical issues that are meaningful for the farmers. 'Practical issues' does not necessarily mean technical and short-term issues: 'grass silage' and 'housing and long-term investments' are two examples of the practical issues we used with the farmers as a start to the modelling process. They led farmers to discuss as various topics as the feed quality, the cows' health, the well-being of the farmer, the ecological footprint, or the farm perception from the 'non-farm neighbour' for instance.

## The methodological route

Our methodological route was devised and tested iteratively. The participatory workshops constitute the core, as it was during these that the conceptual models were built. Nevertheless, so as to prepare these workshops, some prior work was required (i) to identify practical questions to be discussed with the farmers during the participatory workshops, and (ii) to involve farmers and foster their commitment to the programme.

### Preparing the participatory workshops

*Prospecting to identify and choose local change dynamics where the participatory programme could be implemented*
This step consisted in making telephone calls, holding informal meetings and exchanging e-mails and documents with local extensionists. At the end of this first step, two different local promising dynamics had been identified: (i) organic conversions in the Pilat region; (ii) suppressing grass silage in some dairy farms in the Puy-de-Dôme département (France) to improve the local cheese quality. The Pilat region was selected because of the greater willingness of the local stakeholders to

participate in our programme. In all, 33 farmers converting or already converted to organic farming were involved.

*Negociating an agreement to launch the participatory programme*
This step took place during a meeting with the extensionists and the local institutes concerned by the dynamics of conversion. Information was exchanged, and the agreement to launch the programme was negotiated, together with some undertakings by both researchers and stakeholders. For instance, the milk plant and a local extension association made their commitment to supporting our project known to the farmers until a sufficient number of voluntary farmers was reached to launch our programme. We undertook to keep everyone regularly informed of the work done with the farmers.

*Collecting data from farmers and meeting them to prepare the participatory workshops*
A series of individual on-farm surveys was carried out for all the voluntary farmers who signalled their interest in our participatory program by sending back a coupon in reply to a letter we had addressed to all the farmers. These surveys made it possible to identify practical issues that interested the farmers, and initiate a good working relationship with them. Out of the 33 farmers who were addressed by our letter, 15 were interviewed.

*Negociating farmers' participation in the workshops and informing all the stakeholders involved*
At a meeting with farmers, extensionists and a representative of the milk plant, the information collected during the surveys was presented and the farmers were officially invited to participate in the workshops, the principles of which were explained to them during the meeting. At the end of the meeting, two groups of five voluntary farmers had been formed to participate in two successive workshops per group.

### Running the participatory workshops

The participatory workshops were used to build causal maps representing the operation of the livestock farming systems. Cossette (2003) proposed the following route to formalise the strategic vision of a business manager:

- Subjects are asked to identify the most important factors that, according to them, will impact the future of their enterprises.
- They then fill in a grid for each of the previously stated factors to systematically explore them: they write each of them in the centre of a separate sheet of paper. On each sheet, they then write out on the left all the factors influencing the central factor, and on the right all the factors influenced. They then do the same exercise with each of the secondary factors and so on until they are satisfied with their grids. The different factors are joined up with arrows. An arrow starts from an influencing factor and points to an influenced factor. The subjects are told they can write the same factor on the same sheet and on different sheets as many times as they find necessary. Once they are integrated in the grids, all the written factors are referred to as the 'concepts' of the causal map, and the different arrows represent the links between concepts.
- So as to build a subject-specific map, referred to as the 'causal map of the subject', all the different grids of the subject are aggregated by means of the concepts used several times on different sheets.

For our project with farmers, the principles of Cossette's second and third steps (2003) were kept the same (except that our maps were built by a group of farmers rather than by a single subject), but the first step was significantly modified, as it is considered difficult to directly ask farmers about the most important factors in their system (Fairweather and Hunt, 2009). Rather than asking such an abstract question without suggesting any example of factor as a guidance element, we preferred to use the practical questions identified beforehand to initiate the modelling process, as described in Section 1.5. This process aimed at both facilitating farmers' expression and escaping from prior theory in favour of actual practice.

Our methodology for building the causal maps was therefore as follows:

*A first step to have the farmers express possible concepts for the causal maps*
This step took place during workshops that lasted one half-day. One session was organised for each group of farmers. The Métaplan technique (Schnelle, 1979) was used for brainstorming based on the practical questions identified during the surveys. During each session, the group of farmers was asked at least two open questions that had previously been chosen as being of particular interest to the farmers who formed the group. 'Silage on your farm: what does it mean for you?', or 'Calving patterns: what does it conjure up for you?' are two examples of such questions. For each question, each farmer was invited to write down ideas on three to four different memo slips, with one idea per slip. All the slips were then read by all the farmers, potential disagreements discussed, and the slips stuck on a board by the farmers so as to form different groups of slips carrying similar ideas in the farmers' opinions. After the workshop, and on the basis of this display, we formalised a list of all the different ideas that appeared during the workshop, for instance 'healthy animals', 'heavy investment' or 'good ecological footprint'. The farmers' ideas were either kept as written by them, or, where necessary, they were slightly reworded by us so as to appear as potential causes and/or consequences to be further integrated into a causal map.

*A second step to add new concepts and to formalise the links between concepts*
This step took place during another series of half-day workshops, with one session organised per group of farmers. For each group, we chose six different ideas in the group's list of ideas formulated as concepts, as explained above. As we wished them to operate as modelling kernels, these six concepts were topically as different as possible, and we systematically explored each of them with the farmers by filling in a grid, as suggested by Cossette (2003), and as explained above. For each concept, we asked the group to tell us all the factors that could influence it and all the factors that could be influenced by it. During this process, we wrote down what the farmers said and drew the arrows, while repeatedly asking the farmers whether they agreed with what we wrote down. If there was any disagreement within the group of farmers, they were asked to discuss the matter until they arrived at a consensus on the point in question.

*Aggregating the grids to form one causal map per group*
After the workshops, we aggregated the different grids built by the two groups of farmers so as to create one single causal map per group. Aggregating was based on the concepts that appeared on several grids. For most of these concepts, when they were used a second or a third time for example, farmers spontaneously noticed that they had already been written for another topic. A part of one of these two maps is shown in Fig.1.

## Discussion

Compared with carrying out on-farm surveys, as often done to enrich models of livestock farming systems, organising participatory workshops requires a higher degree of farmers' commitment: they have to be willing to take part in two successive workshops and to attend and participate actively. The success of the whole participatory programme is closely linked to farmers' willingness to participate, which also makes it more uncertain. To minimise the risk of failure, our methodology involves asking local extensionists to support the project, meeting farmers individually before the participatory workshops, and favouring open discussion throughout the program.

Furthermore, our methodology does not rely on a well established use of causal mapping. There are few causal mapping studies that focus on farming systems, and the mapping process does not generally include farmers (Fairweather and Hunt, 2009). Those authors suggest a methodology to map farming systems with the farmers themselves, to build accurate representations of how farmers understand their farm systems. In the present study, we rather wanted to build useful representations to foster self-reflection within the group, which led us to choose group mapping instead of using a number of individual maps as done by Fairweather and Hunt (id.). Our group approach was also different from approaches like that of Damart (2006) that strive for collective action and consensus. Our participatory workshops offered some kind of a collective brainstorming, but no action needed to be decided collectively: the practical consequences of such a brainstorming laid at the individual level. Therefore, we did not need to make the effort to precisely define every concept in the maps in a consensual way.

Because of its novelty, our methodology needs to be further explored to better identify its strengths and weaknesses. We already observed a better quality of the mapping process in our first group of farmers compared with the second. The final map was larger (178 concepts in the first group vs. 128 in the second) and more integrated (4 automatic clusters in the first group vs. 5 in the second), and during the workshops, we noticed a best equilibrium in the participation of the different individual farmers. All this might be explained by different factors: (i) a greater proportion of converting farmers within the first group conducive to a greater willingness to exchange ideas about organic conversions; (ii) a lower level of interknowledge of the participants within the first group, which increased curiosity and the participants' eagerness to discuss; (iii) the same composition of the first group of farmers for the two workshops whereas the composition slightly varied from the first to the second workshop in the second group; (iv) the presence of some 'leaders' in the second group who tended to speak more than the others; (v) different meteorological conditions during the workshops that may have focused the preoccupations of the members of the second group on their short-term harvesting tasks. This suggests to pay a special attention to all these factors so as to optimise the results of implementing the methodology.

In spite of such difficulties, our methodology makes it possible to support farmers in the redesigning processes of their whole livestock farming systems. Its benefits for participating farmers can be seen at three different levels: (i) the mapping process can help them to gain a better understanding of the processes at stake during a conversion; (ii) farmers can discover new ideas, can become able to analyse the weak points in their farm operation and identify where their neighbours' experience could help to overcome them; (iii) farmers are made aware of the specificities of their objectives and strategies compared with their neighbours', and they can be able to anticipate their consequences in a more structured way. This appropriateness of the co-designed models is one obvious advantage of farmers' participation. In a next communication, this will be further explored and illustrated on the basis of analysing the maps' content.

Finally, analysing the common traits between the two maps helps to enrich researchers' models of livestock farming systems. These common traits can be some common concepts, some similarities in the topics represented on the maps, or in the ways different constitutive elements of a livestock farming system are linked. They can stem from the fact that the farmers in the two groups, locally involved in the same dynamics of conversion, belong to the same local professional group and therefore share certain forms of knowledge (Darré et al., 2004). However, such forms of knowledge could also be viewed as relevant for the whole 'technical community' if similar results were to be found in different regions (Mathieu, 2004). We will thoroughly analyse these common traits between the two maps and look at how they could enrich researchers' models or help to make them more fully integrated and more closely linked to action and decision. This interaction with farmers' forms of knowledge is another important strength of implementing participatory programmes.

## Conclusion and prospects

The methodology we propose here enabled us to build two different causal maps, the structure of which was defined by farmers. Although work remains to be done to enrich researchers' models with the original forms of knowledge contained in these maps, or derive support tools from our methodology to be used by extensionists, the work presented here still constitutes a first methodological basis for any modelling project that would benefit from an interaction of scientific and empirical knowledge.

Our methodology can also be seen as a relevant tool for system analysis in any project aiming at system innovation conducive to more sustainability at larger scales than the farm scale, e.g. projects that use approaches such as transition management (Kemp et al., 2007) or reflexive interactive design (Bos et al., 2008).

As for any modelling project, the process is as important as the end result, i.e. the model, for the modellers. Here the main modellers are farmers, and the modelling pattern is original: models are built by farmers and are intended to be useful to researchers, whereas the modelling process is useful to farmers, unlike the more classical way of modelling livestock faming systems, where researchers build models and knowledge intended to be useful to farmers.

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