Evaluating innovative scenarios to enhance mixed crop-livestock farm sustainability: a partnership methodology based on farmers' long-term strategies

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Abstract: Mixed crop-livestock farms are once again attracting worldwide interest, as they are considered to be a good way for ensuring the sustainable intensification of agriculture, by limiting environmental problems while allowing productive and economically viable farming. The incentives of the Common Agricultural Policy and decreasing workforce availability have nevertheless marginalised these farms in Europe since 1970. Ensuring the survival of sustainable mixed crop-livestock systems is therefore a challenge for European agriculture. This study aims to develop a methodology for evaluating innovative scenarios in order to enhance mixed crop-livestock farm sustainability. As research studies have evidenced continuity and consistency in long-term farm changes, we assumed that farmers' past strategies should be the basis for relevant future studies. Analysis of farming system dynamics should thus make it possible to define relevant innovations according to farmers' choices, i.e. ones that are more likely to be adopted. A partnership group with farmers, mayors and technical advisers was formed to develop the innovative scenarios through collective meetings. The study was carried out in the French Coteaux de Gascogne, a less favoured area of south-western France, where farms are less specialised compared with other parts of the country. Currently, half of the farms rely on mixed crop-livestock systems. As a first step in our analysis, we examined farm trajectories from 1950 to 2005 to assess the types of long term strategies used by farmers to maintain mixed-crop livestock farming. Four "paths to last" were highlighted in mixed crop-livestock farming. In view of the current trends in the driving forces, the partnership group selected "maximising autonomy" and "diversification of production units" as suitable paths for maintaining mixed crop-livestock systems in Europe. On the basis of these two types of trajectory, we constructed two technical prospective scenarios jointly with local players. In line with the "maximising autonomy" type, forage legume intercropping made it possible to feed the bovine herd self-sufficiently while maintaining soil fertility. In line with the "diversification of production units" type, heifer-fattening enables short-circuit commercialisation. These scenarios have been simulated on local farms and the simulation results were discussed at collective meetings. This methodology made it possible to develop innovative scenarios thanks to i) the strong involvement of local players through collective meetings and ii) an original future study based on a retrospective study integrating long term changes.

Keywords: mixed crop-livestock farming; scenarios; partnership evaluation; trajectories of change; adaptive capacities

Introduction

Mixed crop-livestock farming is the subject of regained interest worldwide in the context of the Sustainable Development of farming (Hendrickson et al., 2008; Schiere et al., 2002). Mixed crop-livestock systems combining arable crops and livestock on the farm scale are said to be eco-efficient owing to their economic and environmental advantages (Ryschawy et al., 2012, Hendrickson et al., 2008). The strong complementarities between livestock farming and crops involving nutrient cycling in particular would limit the negative environmental externalities (Hendrickson et al., 2008; Schiere et al., 2002) while enabling productive and economically viable agriculture. Mixed crop-livestock farms have however been broadly marginalised by the past development of European agriculture where farm specialisation was promoted heavily. This has been aggravated recently by the changes and fluctuations in the markets for agricultural inputs and products. Mixed crop-livestock farms have for the most part survived in areas with a lower pedo-climatic potential. But their future is uncertain owing notably to the lack of a farm labour force – the joint management of two units requiring a large amount of work (Hendrickson et al., 2008; Ryschawy et al., 2013). Limiting the regression of mixed crop-livestock farming in areas where it is still present is therefore a challenge for the future in a perspective of European agriculture sustainability.

This study aims to develop a methodology for evaluating innovative scenarios that will make it possible to enhance mixed crop-livestock farm sustainability. As research studies have evidenced continuity and consistency in long-term farm changes, we assumed that farmers' past strategies – i.e. the long-term strategies implemented by farmers up until the present day – should be the basis for relevant future studies. Analysis of farming system dynamics should thus make it possible to define relevant innovations according to farmers' choices, i.e. ones that are more likely to be adopted. A partnership group with farmers, mayors and technical advisers was formed to develop the innovative scenarios through collective meetings. The study was carried out in the French Coteaux de Gascogne, a less favoured area of south-western France, where farm specialisation is low. Currently, half of the farms rely on mixed crop-livestock systems (Choisis et al., 2010). In this paper, we focus on the methodology we developed to evaluate innovative scenarios for enhancing the sustainability of mixed crop-livestock farms. First, we present the form of cooperation we developed. Then, we focus on our retrospective study, highlighting the farmers' long-term strategies. In the third part, we explain our prospective methodology based on those farmers' long-term strategies and a partnership assessment.

Form of cooperation within the group of partners

Definition of the group of partners

The study was part of an interdisciplinary research project launched in 2008 regarding the long-term effects of relationships between landscape, agriculture and biodiversity on the sustainability of local rural landscapes. It was based on a pluri-annual partnership between a research team (INRA, UMR Dynafor) and a set of local partners from the French Coteaux de Gascogne, e.g. players from the municipalities in the four districts making up the study area, 56 local farmers from the area and two professional agricultural organisations providing advice to farmers. The study itself was carried out at the request of local farmers and was developed for a PhD Thesis in Agronomy (Ryschawy, 2012). The partners for this study consisted of a restricted group of local partners chosen on the basis of their willingness to work together with the PhD student on the future of local mixed crop-livestock farms. The group was thus made up of two local mayors, one agricultural advisor, and fifteen volunteer farmers at the head of cow-calf operations - arable crop mixed crop-livestock farms (seven farms), or specialised in cattle or arable crops.

Learning process

The group of partners decided together to proceed through collective meetings. For each step of the study, the objectives and results were discussed. Perspectives were proposed for the next steps. All the participants were happy to come to the collective meetings. The PhD student's role was to organise and chair the collective meetings. It was made clear between the participants at the beginning of the process that they all had the same right to express their views, and undertook to respect the views of the other participants, such as explained by ComMod (2005). This understanding created an atmosphere of trust for the discussions. The researchers were not seen as experts but as participants in the group and the farmers were able to explain their points of views easily, especially on their empirical experiences. This type of collective functioning proved positive for enabling collaborative learning (ComMod, 2005). In order to analyse the process outcomes for the local partners, we conducted a semi-structured survey two months after the end of the study, asking them what they thought about the whole learning process. This allowed us to hold an individual discussion with each partner after the end of the whole process. Basically, they all pointed out the importance of collaborative learning through discussions between different professions. The local partners benefited from the farmers' objective point of view on the area, and the researchers benefited from the farmers' technical and locally anchored knowledge.

Long-term perspectives for farmers' strategies

Studying farms' past trajectories in order to understand the farmers' long-term strategies

As research studies evidenced continuity and consistency in long-term farm changes, we assumed that the strategies developed by farmers in the past (up until the present day) should be the basis for relevant future studies. Analysis of farming system dynamics should thus make it possible to define relevant innovations according to farmers' choices, i.e. ones that are more likely to be adopted. As knowledge of the past can help understand farmers' long-term objectives, reviewing past changes is a methodological challenge (Moulin et al., 2008). Past changes should not be studied as such, but as a baseline for assessing contemporary and future changes in farming systems. Studying the past could therefore be a way of deducing farmers' long-term adaptive strategies as defined by Darnhofer et al. (2010). In line with Gibon et al. (1999), we assume that an assessment of the variety of historical 'paths of change' on individual farms can (i) provide insights into the farmers' adaptive strategies and (ii) increase their capacity to meet current challenges to the sustainable development of their farms.

A typology combining statistical and empirical analysis

In order to identify innovations that are relevant to the farmers, we started by assessing the variety of the farms' past trajectories between 1950 and 2006. We studied the entire farm population of our case-study site. Data were collected through retrospective surveys in the French Coteaux de Gascogne site, relative to (i) farm structure, (ii) technical-economic practices and (iii) farmers' land-use practices. Historical data were collected on 50 farms using a retrospective semi-structured questionnaire on the evolution of farm structure and function from 1950 to 2006. The data set consisted of 20 variables for 50 farms based on 10-year time steps. We used a two step-analysis combining (i) a visual assessment of the individual farm trajectories, and (ii) a computer-based typology of farm trajectories based on multivariate analyses followed by automatic clustering. We developed a graphic method, inspired by Moulin *et al.* (2008). Each of the 50 individual farm histories was summarised in a synoptic diagram, using graphic conventions. A horizontal timeline represented the six time-steps from 1950 to 2006. Changes in the farming systems were mentioned in the diagram. The visual assessment helped us i) understand the major changes on each farm and ii) select appropriate variables among the 30 available. We assessed the resemblances and differences between the 50 synoptic diagrams to identify the local change trend. The visual assessment allowed us to identify the main variables that distinguished each farm's trajectory.

To identify the similarities and differences in the individual farm trajectories, we used a method developed by Dolédec and Chessel (1987) and adapted it so it could be used to study agricultural changes (Ryschawy et al., 2013). This method allowed us to distinguish between the impact of the farm's environment and that of its structure and functioning, with respect to time. Basically, the total variance of matrix Z is broken down into three orthogonal axes corresponding to the farms, the dates and their interactions (Garcia-Martinez et al., 2008). To build our typology through a Principal Component Analysis (PCA), we selected the table corresponding to the variations between farm trajectories. To build farm groups with a similar temporal profile, we carried out a Hierarchical Ascendant Classification (HAC) on the main PCA factors, using Ward's aggregation method and squared Euclidian distance. We assessed the resemblances and differences between all the diagrams of the farms belonging to each cluster. The visual assessment helped us interpret the strategies and objectives shared by the farmers in each cluster. The detailed classification of the clusters into types of farm trajectories was reinforced by our knowledge of the study area. After reinterpretation of all the types, we presented our final typology to local farmers by means of interviews with 12 farmers. These interviews allowed us to improve our interpretation of the types. As the final step in the process, we organised a collective meeting with 10 local farmers and their adviser. This meeting allowed us to validate the typology and confirm that we had not left out any essential material due to the time step we had selected.

Four "paths to last" in mixed crop-livestock farming

Four "paths to last" in mixed crop-livestock farming were highlighted. Type 1 farmers can be considered to be 'autonomy-led farmers'. Their long-term strategy was to find the best land-use combination for maximising interactions between livestock and crops. Type 2 farmers could be considered to be 'diversification-led family farmers'. Their long-term strategy was to ensure the permanence of the 'household', i.e. the conservation over generations of the inherited family farm. Type 3 farmers could be considered to be 'risk reduction-led farmers'. Their long-term strategy was to secure their farms through a major increase in capital. Type 4 farmers consistently tried to adapt their farm to the family labour force. The availability of a family labour force divided Type 4 farmers into two subtypes. In view of the current evolution of the driving forces, the partnership group selected "maximizing autonomy" and "diversification of production units" as suitable paths for maintaining mixed crop-livestock systems (Ryschawy et al., 2013). This choice was made through a collective discussion with the whole group of partners. On the basis of these two types of trajectories, we have constructed two technical prospective scenarios jointly with the local players. These scenarios will be developed in 2.

Limits and advantages of this step of the methodology

In this step of the study, special emphasis was placed on the interpretation of data, which is partly subjective. Nevertheless, the combination of computer-processing methods limits this subjectivity; the statistical analysis of variables chosen made reference to both conceptual and empirical considerations. Despite their unwieldiness and methodological difficulty, such integrated assessments of the variety of farm change trajectories in local farm populations indeed appear to be an important research orientation for understanding long-term agricultural changes in order to help farmers cope with the major changes currently facing them. This work offers useful material for assessing the farmers' long term strategy for understanding contemporary and future agricultural changes. Our results also provided information of topical interest for understanding the adaptive capacities developed by the farmers to continue their farming system in the long term in upland conditions. Discussions with farmers enabled us to improve our interpretation and confirm the trends we had identified. This study is an illustration of the interest of participatory research with farmers and other local players. Farmers contributed considerably to improving the study by giving us access to their local knowledge. Indeed working with local players appears to be a particularly valuable approach for improving our understanding of changes in farming systems (ComMod, 2005).

Change trajectories as the first step of a prospective study

This first step of the study provided insights into the variety observed in the 'paths to last' followed by local farmers in the same environmental, political and economic context. It made it possible to highlight two specific past strategies of farmers favourable to enhancing mixed crop-livestock farms. As research studies have evidenced continuity and consistency in long term farm changes, we assumed that studying the long term strategies of farmers should be the basis for relevant future studies. The mobilisation of a retrospective study of the pathways for surviving in mixed crop-livestock farming based on quantified data going beyond simple estimates or various people's subjective opinions should make it possible to develop prospective thoughts anchored in farmers' strategies. We assumed that this basis for a prospective study should increase the probability of the future scenarios being adopted even if the length of the study did not make it possible to verify this formally. Analysis of farming system dynamics should in fact make it possible to define relevant innovations according to farmers' choices, i.e. ones that are more likely to be adopted.

A participatory assessment for identifying the scenarios

General prospective approach

The approach adopted for the prospective study follows a three-step process typical of exploratory methods (Börjeson et al., 2006): 1. Conceptualisation of the prospective problem and choice of scenarios, 2. Exploration of the scenarios and 3. Evaluation of the scenarios (Figure 1). Step 1 was carried out by means of meetings with the local partners to collectively identify technical innovations favourable for maintaining mixed crop-livestock farming on the local farms. Step 2 was based on an individual interaction between a researcher and two farmers with a view to constructing and evaluating the innovative scenarios chosen in Step 1 on their respective farms. Step 3 was conducted in two complementary ways: by means of a group discussion on the individual results of the Step-2 simulations (Step 3.a.) and by complementary simulations of these scenarios in contrasting future political and economic contexts (Step 3.b.).

Identifying the scenarios with the partners

Four collective meetings between the group of local partners and the researchers, each lasting a half day, made it possible to identify technical innovations favourable for maintaining mixed crop-livestock farming in relation with the two "paths to last" identified through the retrospective study (Step 1.a.). The "Autonomy" strategy (A) is based on the maximization of feed self-sufficiency for the farm's animal herd through close coordination of crop and livestock production. The "Diversification" strategy (D) is based on a diversification of the production units in order to benefit from economies of scale (?) and secure the farm with respect to price (?) fluctuations not only for the inputs but also for farm products. We translated them into technical scenarios to be implemented on local mixed crop-livestock farms (Steps 1.b and 1.c).

A simulator understandable by all the partners for evaluating the scenarios

Once the technical innovations had been made clear, the local partners wanted to simulate their implementation on real farms, to obtain locally quantified results and assess the scenarios on concrete cases. Exploration by computer simulation was chosen for its capacity to quantify ex-ante the effects of an innovation and stimulate the discussions between researcher and partners (Martin et al., 2011). A whole-farm simulation tool called CLIFS (Crop Livestock Farm Simulator) was adapted to conduct these simulations and evaluate each scenario (see Le Gal et al., 2013 for an earlier version based on the same design principles) (Step 1.e). CLIFS makes it possible to design different future configurations of a mixed crop-livestock farm according to the producer's development projects. Up until now it has been used as a support for advising mixed crop-livestock farmers in tropical regions (Brazil, Madagascar, Peru). CLIFS calculates the annual balance between the supply and demand in fodder biomass and organic fertilizer based on the needs and production of animal and crop units. The balances are focused on the technical functioning of the production system, in particular on two fundamental levers for interactions between livestock and crops within a mixed crop-livestock system: animal feeding and organic fertilization. Two farmers (one per strategy) volunteered to have the simulations carried out on their case (Step 1.d.).

For instance, in the farm's "maximizing autonomy" strategy (Case A), the farmer has settled (aged 50) into a steady state of operations. He already has a working organisation that suits him and wants to think in terms of innovation while limiting any increases in his workload. In particular he wants to improve his self-sufficiency with respect to feed for his herd with the goal of being able to stop purchasing concentrates and possibly improve the reasoning behind his rotations, even though he already has diversified rotations combining the production of cereals, oil protein crops followed by five years of alfalfa. The prospective innovations chosen were characterised with each farmer by calling on the expertise of regional technical organisations. In each case, a baseline scenario was constructed to begin with, aiming to reproduce the current situation on the farm and making it possible to calibrate certain variables such as the yields, in particular the grass production of the different pastures for which there were not many local references available. Table 4 gives the comparison between the baseline scenario S0 and the real data for the farm concerned. Two scenarios (S1 and S2) were then defined for each case and simulated with CLIFS (Step 2).

Combining step-by-step assessments with individual farmers and collective meetings to evaluate the technical scenarios

The scenarios specific to each farmer were assessed step by step with them to adapt the scenarios to their goals while remaining coherent with the definition of the general scenario that they represented. Two indicators were chosen: the Total Gross Margin for the economic dimension, and the annual Nitrogen Surplus (NS) for the environmental dimension. These two indicators are known to distinguish between the levels of sustainability on mixed crop-livestock farms (Ryschawy et al., 2012). The TGM percentage for livestock farming made it possible to evaluate how the scenarios tilted the balance of the farm's configuration towards livestock or crops, with the farmers wishing to keep a balance. An additional analysis based on the "work assessment in livestock farming" method (Hostiou and Dedieu, 2012) made it possible to analyse the feasibility of each scenario regarding work organisation. Scenarios S1 and S2 were adapted to make it possible to put them into practice without requiring any additional manpower. Their final configuration sought to satisfy both the reasoning adopted collectively and the goals specific to the farmer. The results of the simulations were evaluated at a collective meeting held with the local group of partners. The quantified results were presented by the two farmers themselves. Each of the participants then gave their views on these results and on any possible threat they saw regarding their implementation. The farmers were thus able to assess the possible relevance of the chosen prospective innovations.

Action-oriented knowledge for the local partners

As emphasised by Martin et al. (2011), partnership approaches must provide not only scientific knowledge but also so-called actionable knowledge, i.e. knowledge that is pertinent for the local partners involved. The objective eye of research allowed them in particular to "understand better the evolution of local agriculture" and stand back to assess their strategies. At the time of the ex-post evaluation of the approach the farmers' pinpointed what they had learnt at the level of their overall economic approach to their farm. They said they were used to seeing TGMs analysed by their advisors without, however, having taken any particular interest in the past. This integrated approach allowed them to understand *"that everything isn't always a race"* and that *"the performance would be to know when you are spending too much to produce"*. This confirms the importance of the paradigm of the systemic approach (Darnhorfer et al., 2008; Gibon et al., 1999) and of a holistic approach to the farm, as proposed by Schiere et al. (2002) with their "communal ideotype" principle, whereby good system productivity is more important than a good productivity of the system's component parts taken separately. These principles have been found to be highly relevant on mixed crop-livestock farms, based on close interactions between units, which constitute as many levers for improving the farm's overall performance.

Through this approach the local partners have also acquired new technical knowledge relative to the targeted innovations. The simulations on real cases have enabled the farmers to discuss their experiences and *"see what could be feasible or not locally"*. The localised dimension of the work was of particular interest to the farmers leading them to say that *"the subject was really relevant to them, and with concrete results for once"*. These results therefore served as the support for creating a rich and enthusiastic collective discussion, by stimulating a reflexive and interactive analysis, the importance of which has been emphasised by other authors (ComMod, 2005; Martin et al., 2013). The partners also appreciated the fact of being able to share their views on farming with each other and with *"other professions that could take an objective look at the local situation"*.

Conclusion

The originality of the approach adopted lies in the combination of collective discussions over time with a set of local partners, and of simulations on concrete cases of farms chosen by mutual agreement within the group. It also lies in the mobilisation of a retrospective study of the pathways for surviving in mixed crop-livestock farming and of prospective thoughts based on quantified data going beyond simple estimates or various people's subjective opinions. This set of methods proved to be a factor for the successful mobilisation of the local partners and for ensuring that the alternatives proposed were anchored in their reality. This process increased the probability of these alternatives being adopted even if the length of the study did not make it possible to verify this formally.

The creation of a group of local partners with different profiles ensured a lively dialogue between researchers, different types of farmers and a variety of professions. If we add to that the handling of various types of technical, economic and social data and information, the process made it possible *in fine* to cross-reference a broad range of empirical, technical and scientific knowledge, and enrich learning, both individual and collective alike. The ex-post evaluation allowed us to ensure that local partners not only acquired concrete technical knowledge but were also able to rethink their approach to their farms through the communal ideotype.

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Figure 1: Implementation of the prospective approach (adapted from Martin et al., 2011)