Innovation and development in agricultural and food systems

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Chapter 10

Co-designing technical and organizational changes in agricultural systems

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Summary. The transformations currently underway in agriculture are throwing the spotlight on the studies and methods currently used to design innovative farming systems. This chapter analyses the specificity of five approaches for co-designing technical systems that have been tested in France and in some African and Latin American countries. They are based on a high level of interaction between actors involved in these approaches, and are facilitated by a range of intermediary objects such as modelling tools and agricultural experimentation in a rural environment. They have led to the production of operational and scientific knowledge on technical changes and the conditions under which they can be implemented at the farm level, as well as the institutional conditions conducive to the emergence of new systems. These approaches rely on skills that go beyond those pertaining to agronomy alone; the inclusion of social science researchers may become necessary, in particular to analyse how to hybridize various types of knowledge in order to accompany innovation on farms and in territories.

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Agriculture is addressing new challenges. It needs to become more efficient in order to meet increasingly important societal expectations, such as the reduction in pollution caused by the use of fertilizers and pesticides, a reduction in energy consumption and greenhouse gas emissions, the maintenance of biodiversity and access to a healthy and balanced diet (Schaible and Aillery, 2017; Brooks, 2014).

These challenges require agricultural innovation to be supported in its technical, organizational and institutional dimensions (Chapter 3). The farmer plays an active part in this process. He can no longer be relegated to the role of an end user, adopting technical proposals originating from the research community, but instead becomes a co-designer of innovation (Chapter 8). Such a shift requires an in-depth review of the studies and methods used to design innovative farming systems (Meynard *et al.*, 2012).

These studies focus on the development of methods for the design and assessment of farming systems at several levels (Meynard *et al.*, 2012), from the plot or the herd to the farm or the territory. Agronomists analyse, on this basis, the short- and long-term effects of innovations (varieties, pesticides, fertilizers, biotechnologies, and cropping, livestock and irrigation methods) by taking into account the changes they are likely to induce on production systems, territories and value chains. This knowledge is used to design new cropping and livestock systems, combining scientific knowledge with the empirical knowledge of the actors directly involved.

Design processes are by nature diverse. Hatchuel *et al.* (2006) differentiate two main types. In the first, the design process is systematic, with the knowledge and expertise required available at the beginning of the process. The design goals and validation processes (prototypes, trials, tests, division of tasks) are clearly defined in advance. In the second, the innovative design aims to meet new expectations that were not explicitly defined at the outset. Through a process of dialogue, actors decide on multiple goals as the design process unfolds. As an extension of this distinction, Meynard *et al.* (2012) specify a *de novo* design and a step-by-step design in agriculture. The *de novo* design is oriented towards the invention of systems (crops, livestock husbandry, production) that represent a break from existing systems. It is accompanied by the drawing up of scenarios, which allow the exploration of a wide range of possible future situations involving profound changes. But this approach does not focus on the transformations needed to move from the current system to the innovative system (Prost *et al.*, 2016). In contrast, the step-by-step design seeks to recommend and implement changes or evolutions based on iterative assessments and learning loops. In this incremental approach, the farmer gradually develops his new system, all the while learning to manage it, even as he convinces himself of its benefits and reorganizes his work and his means of production accordingly.

Basing themselves on a review of the literature, Le Gal *et al.* (2011) fine-tune the reflection with a typology of design approaches. They highlight 'design-oriented' approaches, in which the actors' participation is limited, and 'design-support' approaches, in which the focus is on supporting the actors in a process of technical and/or organizational changes. The first type includes prototyping and modelling approaches. The second includes 'participation-based' approaches aimed at building up the capacities of actors without recourse to modelling; 'support-modelling' approaches based on the use of modelling tools and actor participation to compare different technical alternatives; and, finally, 'advisory-oriented' approaches to provide advice to farmers. These participatory processes are especially important for creating new knowledge, learnings, technologies and products that are useful for farmers (Berthet *et al.*, 2015). Indeed, in these processes the management of the interactions between stakeholders of the action-research process is key to better combine or hybridize multiple forms of knowledge. They use specific exploration tools to do so, which facilitate mediation and the development of a common language among partners. These tools thus play the role of intermediary objects (Vinck, 1999).

The goal of this chapter is to analyse the specificity of the approaches for the co-design of technical systems used by its various authors, by positioning them and comparing them to others referenced in the literature. To this end, we present five case studies of approaches that aim to build methods, tools and mechanisms for the co-design and participatory assessment of technical systems in varied contexts.

The technical system corresponds to all the technical means and management practices of crop or livestock systems used by a farmer at the farm level to obtain results by mobilizing factors of production and decision-making rules (Osty, 1996). This concept allows the consideration of a broad range of studies, such as the assessment of the performance of production units and the farm, the analysis and support of the farmers' decision-making processes or the way in which they allocate their resources for agricultural and livestock production.

The common feature of the five case studies analysed is the relationship between the farmer and the technique, which incorporates the diversity of types of agriculture (organic farming, agroforestry, conservation agriculture, mixed farming systems), in the countries of both the Global North and the Global South, in order to support the innovation processes that take place at the farm or territorial level (agrifood supply basin, spaces shared by various actors).

As suggested by Berthet *et al.* (2015), we analyse the approaches implemented for the co-design of technical systems according to three dimensions: the type of interactions between actors, the type of intermediary objects mobilized with the actors, and the results obtained by these approaches. We also position these co-design approaches with respect to the starting point chosen by the designers to support the evolution of the practices, as defined by Doré and Meynard (2006), namely the knowledge on the biophysical functioning of the productions concerned, the technique, and the rationale behind the action.

41. The types of interaction between actors in the co-design of technical systems

The five approaches analysed (Table 10.1) are based on interactions between researchers and farmers. Some also include actors of advisory services, or even institutional actors.

Table 10.1. Characteristics of the five approaches studied for co-designing technical systems.

Case study	Objective	Study area	Actors involved	Source
Improvement of cotton-cereal-livestock systems (French abbreviation: ACCE)	Improve cotton-cereal-livestock systems in the context of growing human pressure and degradation of natural resources	North Region of Cameroon	Farmers and advisers of the Cameroon Cotton Development Corporation	Djamen Nana *et al.* (2003); Dugué and Dounias (1997)
The Integrated Assessment of Agricultural Systems approach (IAAS)	*Ex-ante* definition and assessment of future agricultural scenarios, involving the rice farmers' organization and the Camargue Regional Nature Park, especially for the extension of the conversion to organic farming	Camargue	Rice farmers' organization, Camargue Regional Nature Park	Delmotte *et al.* (2016)
Agroecology-Based Aggradation-COnservation agriculture (ABACO)	Conduct tests with actors in the field on the technical and organizational feasibility of conservation agriculture in sub-Saharan Africa	Burkina Faso	Farmer organizations, advisers, traditional authorities, technical services	Dabire *et al.* (2016)
The Crop LIvestock Farm Simulator approach (CLIFS)	Help farmers who are undertaking a medium- or long-term evolution of their farms in their reflections on possible avenues to use co-constructed scenarios	Brazil, Morocco, Peru, Madagascar, south-western France, Burkina Faso	Farmers, advisers	Le Gal *et al.* (2013)
Decision-making support implemented by students of Montpellier SupAgro (SupAgro)		Camargue	Students, educational team, farmers	Michel *et al.* (2018)

The ACCE (Improvement of cereal-cotton-livestock systems) and CLIFS (Crop Livestock Farm Simulator) approaches additionally target the adviser, which has repercussions on the person in charge of using the co-design tools, and on their transfer to actors in the field. The ACCE approach is based on steps that rely on the adviser's expertise, especially during farm experiments, to develop and validate technical innovations with farmers and to monitor, over an annual cycle, the resulting changes in the management of certain production units and resources. As for the CLIFS approach, it is implemented by the farmer with the support of an interlocutor who could be an adviser. The CLIFS approach simulates and assesses an initial scenario, followed by scenarios of strategic change desired by the farmer based on his production goals and the performance of the simulated scenarios.

In the IAAS (Integrated Assessment of Agricultural Systems in Camargue) and ABACO (Agroecology Based Aggradation Conservation Agriculture) approaches, several actors of the farmers' institutional environment are involved. The IAAS approach involves farmers and local institutions dealing with agricultural issues. The commitment of these actors to the project is formalized, and their perceptions of changes in and the future of agriculture in the territory are taken into account, as are their criteria for appreciation and performance. They are then involved in the subsequent steps of the process, i.e. simulation and discussion of change scenarios at different scales (plot, farm, the Camargue region). In the case of the ABACO approach, an innovation platform composed of two bodies is formalized:

- a technical body, composed of representatives of cotton farmer organizations and livestock farmer organizations, and technical services, which is responsible for co-designing cropping systems based on the principles of conservation agriculture;
- an institutional body, made up of traditional authorities, of cotton farmer organizations and livestock farmer organizations, and technical services, which is responsible for dealing with issues of access to markets, to crop residues and to land.

The interaction between researchers and actors in the field is crucial in all these approaches, both to produce knowledge on the technical systems being implemented and to co-construct alternatives. This partnership is often informal in nature. Nevertheless, Vall *et al.* (2016) show the importance of formalizing it by creating a goal that is shared between the partners and by defining a set of specifications to adhere to. Such an effort is conducive to effective changes, since they are the result of the commitment of the actors.

42. The types of intermediary objects in the co-design of technical systems

In all these five approaches, we observe the important role of intermediary objects based mainly on the use of modelling tools or experimentation.

This important role of modelling tools is observed in other studies in the literature on co-design (Duru *et al.,* 2012; Moraine *et al.,* 2016; Stark and Fanchone, 2014). It allows the revitalization of an agronomy of practices – sometimes considered too descriptive and limited to an *ex post* assessment – by more prospective approaches. Modelling tools can be used at different co-design stages to represent the objects under study, simulate their evolution or assess them *ex ante*.

The use of experimentation as an intermediary object in co-designing is also very common in studies on the prototyping of cropping systems (Rapidel *et al.*, 2009; Le Bellec *et al.*, 2012). It allows the farmer to assess the feasibility of the technical changes on his own, with some help from the researcher.

In three of the five approaches studied, modelling tools take different forms. These include using spreadsheets, bio-economic or multi-agent models, as well as cartographic representations. The aim of these tools is to both summarize and link the knowledge on existing technical systems and, most importantly, to explore changes with actors.

Thus, the CLIFS approach is based on the use of a simulation tool dedicated to mixed crop-livestock farms, which can be understood by farmers and advisers, both in its structure and in its calculation procedures and output variables. The calculation tool can be used by the farmers and can be transferred to agricultural advisers. This simulation tool serves as a basis for dialogue between the researcher and the farmer – and the adviser, should one be involved – concerning strategic changes on the farm.

In the approach used by the students of Montpellier-SupAgro, they made a conceptual model of the crop planning and rotation rules, the organization of the work over the year, and management of the cropping systems. They then designed very simple computer models: cartographic representations of the plots using geographical information systems and spreadsheets with the rules for organizing the work. These tools allow students to test the changes a farmer would like to introduce, while representing the possible steps for their implementation on the farm (for example, introduction of a new crop or conversion to organic farming). The results of the simulations are discussed by the students and with the farmer, and studied with regard to the impacts and the feasibility of these changes on his farm.

The IAAS approach also uses modelling tools as a basis for discussion with actors in different arenas (participatory workshops, more formal meetings with institutional actors), but uses three different types of tools: crop models, to describe the performances of conventional and organic cropping systems; a multi-agent model, used during collective sessions with farmers to identify possible technical paths of evolution towards organic farming; and a bio-economic model, for a multi-criteria assessment with local actors of different options for the extension of organic farming at the farm and regional scales.

In the ACCE approach, experimentation, followed by the presentation and discussion of results, was the main intermediary object. The shared diagnosis made by researchers and farmers of farm operations and the sharing of rules of calculation to better assess fodder stocks are also intermediary objects that help promote discussion on technical and organizational changes on farms.

As part of the ABACO approach, several intermediary objects have been proposed to facilitate innovation platforms:

- individual experimentation by the farmer with cropping systems based on the principles of conservation agriculture, so that he can assess their feasibility;
- computer simulation of farm performances, with a limited number of farmers, to discuss the possible links between cropping and livestock systems;
- territory-scale maps, to discuss with the farmers the creation of village zones dedicated to conservation agriculture.

43. The results of these approaches for co-designing technical systems

These different co-designing approaches analysed have led to different kinds of results.

43.1. Design of tools and methods appreciated by farmers

In general, the farmers appreciated the capacity of the tools and methods used for incorporating the different components of the farm in a holistic approach, and for comparing different options and their effects on the management of production factors and on performance. This was especially the case for the CLIFS, IAAS and Montpellier-SupAgro approaches. The quantitative assessment of possible future changes, which were carried out for their own farms and not for hypothetical cases, and the realistic nature of the simulated scenarios were also appreciated.

The different approaches also led to the design of methodological tools that can be useful in other situations. The CLIFS software can be used not only for other farms in the same area, but also in other countries, albeit with some adaptations. The IAAS approach has resulted in a generic method of integrated assessment of production systems that can be used to analyse a variety of indicators at different scales (farm and territory).

43.2. Operational and scientific knowledge of technical changes and the conditions necessary for their implementation at the farm level

These approaches make it possible for researchers and farmers to co-construct shared visions and to explore possible futures, as observed in other similar studies (Martin *et al.,* 2011; Moraine *et al.,* 2016). They have thus made it possible to explore along with farmers paths to technical improvement such as conservation agriculture, insertion of fodder crops into rotations, more intensive husbandry of certain draft and livestock animals, production of organic manure, and changes in rotation or crops.

The conditions necessary for implementing these technical changes on the farm could also be apprehended, mainly with regard to labour requirements, cash and income management, and/or crop rotation choices. The CLIFS and SupAgro approaches have more specifically made it possible to discuss with the farmers the strategic orientations possible in terms of production units and also to determine the size of these units (the size of a dairy herd and the crop rotation to be adopted, for example). This enhanced knowledge of the actors is an important prerequisite to changes in practices and transformations of cropping and livestock systems.

Using a co-design approach to market gardening systems, Dogliotti *et al.* (2014) were able to analyse the effects on the practices of the farmers participating in the experiment. Observing changes in practices is much more difficult when the approaches are aimed at orienting the farmers' strategic choices, but this analysis of the approaches' effects remains useful for improving our ways of interacting with the actors. This type of analysis was undertaken as part of the ABACO approach, which led to an improvement in the farmers' knowledge of conservation agriculture and to the beginning of the adoption of these innovative systems. Similarly, Sempore *et al.* (2016), having implemented an approach of individual support similar to that of CLIFS, have shown its positive effect on practices, the result of an improved knowledge of the flows between cropping systems and livestock systems.

It therefore seems important to improve the assessment of these approaches' effects, which may take the form of a stimulation of learning, tangible decisions taken by farmers, or the adoption of new co-designed technical systems and their impact on food security or incomes.

43.3. Scientific knowledge on the institutional conditions conducive to the emergence of new systems

These approaches also helped identify institutional conditions that are conducive to the emergence of new production systems. While these conditions were sometimes taken into account in the methods and models used, in other cases, they were only revealed during the discussions with the actors involved. They include, for example, the need for collective action or shared equipment, the importance of the supply of inputs and seeds, and enhanced land tenure security (ownership, rental, sharecropping), topics that were addressed at the end of the discussions within the framework of the ACCE approach. In the IAAS approach, the consequences of a change in public agriculture support policies (reduction of direct aid to farmers for cultivation, strengthening of agri-environmental measures) on crop rotations on farms and on the use of the territory's agricultural area, as also the consequences of changes in land use on environmental, economic and social indicators, were more explicitly incorporated into the modelling tools. The limitations of a more widespread adoption of organic farming in the territory were discussed, as were the complementarities between different forms of agriculture being practised in the same space.

Some of these studies led to recommendations addressed to development actors for facilitating changes on a larger scale. In the North Region of Cameroon, the ACCE approach has led to the setting up of regional development programmes and new rules for the management of space at the village level and for the functioning of farmer groups for managing the stock of an input required for livestock husbandry (veterinary medicines). The IAAS approach and some of its results were used by representatives of the Camargue Regional Nature Park to help draft local agri-environmental measures. The ABACO approach has also made it possible to define new rules for access to crop residues at the collective (village) level and to start deliberations on land charters.

44. Conclusion and perspectives for the evolution of approaches for co-designing technical systems

The approaches for co-designing technical systems presented in this chapter bolster the managerial capacities of farmers so that they can develop solutions on their own to address the issues they and their families face. To this end, they use various intermediary objects, facilitating the development of a common language between the partners in the approach and the exploration of possible futures. The innovations co-designed in these approaches concern technical objects (the soil management), a complete system (a cropping or production system, for example, for multicrop-livestock farms) or an organizational change (management of labour and equipment), which are resituated within the farm and the territory.

Current transformations in agriculture, especially those based on agroecology, have thrown the spotlight on these approaches for co-designing technical systems to support farmers. However, they also call for the strengthening of interactions between farmers and other concerned actors (mainly those belonging to food systems, when it is a matter of improving food security, or those involved in ecosystem management, when it is a matter of preserving natural resources). These interactions with multiple actors can be decisive in orienting innovations (choice of innovations, feasibility and acceptability).

The authors of these research studies all mention processes that require skills which go beyond those pertaining to agronomy alone, for example, for assessing learning or for understanding issues concerning scaling of transformations. These constraints raise the issue of the configuration of action-research mechanisms, which may require the inclusion of social science researchers.

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