Agricultural systems and the innovation process

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Abstract

Why dedicate today such a symposium on animal production to innovation and the evolution of this notion in the Mediterranean area? Because innovation has become crucial in an uncertain world: innovation to anticipate, to adapt, to remain competitive or even to survive. In the near future, what would be the keys of the evolution of livestock systems? How to support the innovation process, how to guide it, how to articulate innovation with research and extension? We have shown that, in the present context of increasing globalization, the innovation process is core to multiple tensions that the actors of innovation cannot ignore. Facing such tensions, we suggest to take into account the need to prepare a range of solutions; but also to anticipate the economical, social and environmental effects of innovations; and more broadly, looking forward to the consequences of their emergence and dissemination on the development of agriculture and territories. Then, we have elaborated some proposals to stimulate capabilities of the livestock sector to innovate: how to create new ways of producing? If a model-based design is adapted for exploring breaking systems, a step-by-step design gives more room for learning process and reducing risk. So, it is suitable for a progressive involvement of breeders. However, methods for rule-based innovation (whose aims are fixed) are no more usable when aims are questioned (for instance by dramatically new environmental or social stakes). New competences are then required and new validation criteria should be invented. Such a process of exploration should be called 'innovative design' whose sources are themselves diversifying.

Keywords: innovative design, livestock system, farming system, collective learning

Introduction

In this symposium dedicated to innovation in livestock systems, many examples of innovative systems will be presented to us. The programme reveals a very great diversity of innovations, both for the processes which led to them, for their audacity and for the people involved. There is no doubt that the discussions will be very rich and varied.

But why dedicate such a symposium to innovation today? A first reason is that innovation has become vital in a world that is changing very rapidly: we must innovate to anticipate or innovate to adapt, innovate to remain competitive or innovate to survive. How then can we encourage and guide the innovation process, how can we structure innovation with research and development?

A second reason, just as important as the first, is that the globalisation of exchanges and technological developments can amplify the impacts of innovations to a frightening degree: a technological innovation can radically change production conditions, as well as the living conditions of some people involved in agriculture and territories. We saw it in South America for GM varieties of herbicide-tolerant soybean. If innovation benefits from powerful means of distribution, it can spread at very great speed. So if it has negative effects, it can soon create disasters. How do we evaluate an innovation, before its dissemination or after, to appreciate not only the expected benefits but also the resulting risks?

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These are some of the questions that will be put in this symposium and for which it seemed useful to suggest some lines of thought in this introduction.

In the first part of this presentation, we will show that, in the present farming context, the innovation process is at the heart of many tensions, which those involved in innovation cannot ignore. Then we will attempt in the second part to make a few proposals aimed at developing and stimulating the capacities of the farming world to innovate: what can be done to invent new ways of producing?

Innovating to prepare a diversity of futures

The driving forces of the future evolution of farming practices

What are, and what will be in the next few years, the driving forces of the evolution of farming systems? We have identified four of them, whose importance varies according to agricultures and countries.

The degradation of the ecosystems and the recognised responsibility of agriculture

According to the *Millennium Ecosystem Assessment* (http://www.millenniumassessment.org/en/index.aspx), carried out under the aegis of the United Nations, and published in 2005, concludes very clearly:

'In the last 50 years, mankind has generated changes to ecosystems more quickly and more extensively than at any other period in the history of humanity, mainly to satisfy a rapidly-growing demand for food, fresh water, fibre and wood for building and energy. This has led to a substantial loss of the biological diversity on Earth, a high proportion of it irreversibly…and a reduction in the advantages which future generations can draw from ecosystems.'

The diagnosis identifies agriculture as responsible for:
1. The degradation of the quality of surface and ground waters, of soils (contaminations by pesticides, heavy metals, erosion...), and of the air (greenhouse gases).
2. The loss of biodiversity (disappearance of breeds or varieties, homogenisation of habitats, mortality due to pesticides and deforestation…).
3. The exhaustion of non-renewable resources (fossil fuel, fertilisers).
4. The increase in risks of catastrophes (floods, mud-slips…).

The 'Livestock's long shadow' report refines this diagnosis as far as livestock is concerned, identifying in particular the emission of methane by ruminants. The effects of farming practices on the environment are not felt only at local level: the production systems of the countries of the North and South interact via trade in goods and the establishment of world prices. As stressed by the *Ecosystem Assessment*, solutions will have to combine profound changes at political and institutional levels with a change in practices. Without waiting for political decisions to be made, it seems indispensable to anticipate changes in farming practices aimed at (1) better control of pollutions and soil degradation, (2) greater autonomy as regards non-renewable resources and (3) creating a synergy between conservation and use of biodiversity.

The necessary competitiveness of production systems, in a context of the globalisation of trade

World trade results in considerable fluctuations in prices for many agricultural products. This leads to farmers rethinking their production choices and diversifying their activities on the farm. In a context of food crisis, the imperative for world production to grow is imposed on everyone. In some countries of the South, the food-producing agricultures, historically destabilised by imports of cheap food products, now have to be rebuilt. In the North, whole territories, whose business activity was based on monoproduction that is now in crisis (wine, sheep farming…), are looking for new production systems. To ensure the competitiveness and continued existence of Mediterranean agricultures, solutions will have to be found to confront problems of climate and parasites increased by global changes. Innovations in work organization must be found (Dedieu *et al.*, 1999). Flexible, reactive farming systems must be promoted that can adapt to the instability of market prices or changes in quality standards. They must also be prepared to adapt production systems and business locations to a huge increase in the cost of energy (Boiffin *et al.*, 2004).

The evolution of consumer expectations and industrial demands

Whilst at international level, the *Codex Alimentarius* attempts to standardise minimum qualities beyond which no obstacle to free trade may be placed, competition is based more and more on the differentiation of products (Allaire, 2002). The markets, which used to be governed by sectional agreements related to standard quality, are now increasingly segmented. Processing companies and even the mass distribution multinationals are increasing the number of contracts imposing specific quality criteria on the product or restrictive specifications on crop or livestock practices. So qualification issues are evolving from the product itself towards the definition and control of how it is obtained (origin, production methods). Transforming farming systems not only involves the identification of production methods suitable for obtaining products of the desired quality (technological quality, taste, health quality…) or territorial typicity (Casabianca and Matassino, 2006), but also the drawing up of specifications in a contractual framework (how, for example, can specifications be set up without limiting technical choices and preventing innovation?). It also involves measures to coordinate farmers and industries at territory level (Moity-Maïzi *et al.,* 2001). The acute sensitivity of consumers to products health quality leads to questionings about ways of controlling plant and animal diseases: the tension between the need to minimise the use of pesticides and veterinary products and limit residues in food (and the environment, see above), and the need to guarantee, with a high level of security, the absence of toxins or pathogenic micro-organisms in food products, calls for the mobilisation of alternative methods of controlling animal and plant diseases.

A profound transformation in relationships between agricultures and territories

The transformation of farming systems cannot be conceived independently of the non-farming players in the territory: compromises, arrangements or synergies must be sought with them.

In a context where the economic and social role of agriculture is being marginalised in an increasing number of territories, particularly on the Northern shore of the Mediterranean, farmers are perceived as having a mission to manage space and natural resources, and no longer just to produce. Depending on the characteristics of the territories, specific questions are asked: what sort of agriculture is possible in an outlying suburban area, what are the opportunities and constraints of this type of territory? How can competition for water resources between agriculture and other users be managed? What crop or livestock systems are possible in areas of environmental interest, where the ‘production of the environment’ can become a priority over the production of food? What combinations of activities are possible in touristic areas, between farming production, product processing, direct sales, welcome to the farm, and work outside the farm? Farming activities must be organised so that they can coexist with and complement other uses of the area, other rural activities and the lifestyle quality of residents and tourists. The transformation of farming systems cannot be conceived independently of the non-farming players in the territory, and compromises, arrangements or synergies must be sought with them (Boiffin *et al.,* 2004). At the present time tools are lacking which could make it possible to anticipate and prepare the transformation of cropping or livestock systems around territorial issues: diagnostic tools to locate and give a rank order to the practices to be improved within a given objective;

tools to enable all the players in the territories to share a representation of the agri-ecological and socio-economic consequences of different scenarios of action and dialogue…

Innovation, at the heart of many tensions

Very diversified attempts at innovation

The transformations of production systems which will result from the combined efforts of these driving forces (Poux, 2006) will not occur without tension:

- The classic tension between economic and environmental requirements, illustrated in France by the tension between the high productivity, based on high yielding cultivars, and intensive use of fertilizers and pesticides, and the growing demand of society for a reduction in inputs, and pesticides in particular. The additional work load which handicaps the development of some environmentally-friendly practices can also be cited.
- The tension between individual farmer's decisions and territorial dynamics: for example, the choice of all the farmers in a region being concentrated on the most profitable activities, or on the 'best' breed of a given species, creates genetically homogeneous areas that are favourable to the spread of epidemics.
- The tension between sectors of a same territory, associated for example with competition between different productions for territorial resources (high potential soils, water…). For example, we can quote tensions between cattle farms in the Alps where contrasting productions exist in a heavily-urbanised environment: on the one hand 'cheese-producer' farms dedicated to high quality cheeses using local breeds, difficult lands and high summer pastures, and based on limited productivity per cow; on the other hand, very intensive « dairy » farms involved in mass production sectors, which are a heavy burden on the management of resources and the location of activities.

However, apart from general trends such as the inescapable and increasing influence of environmental questions, it is difficult to predict in ten or twenty years' time, evolutions in the socio-economic context, international agreements, public policies, local arrangements, movements of opinion and power struggles between pressure groups. So the relative influence of the various driving forces in transforming farming systems remains uncertain. Among the players in agriculture and Research and Development there are great divergences about the relative importance to be given to the different driving forces and therefore in the prospective definition of the innovations agriculture would need (Lémery, 2000). The diversity of possible futures is combined with the diversity of local situations (according to the soil and climate condition, the biological and cognitive resources, and the economic, social and cultural dynamics of the farming territories), endlessly multiplying the need for innovation (Meynard *et al.,* 2006).

In addition, it would be naïve to think that all the players whose decisions have an impact on farming systems (from farmers to breeders, from consultancies to public authorities, from agro-supply firms to the food business) have the same short or long term interests and objectives. The same innovation can therefore, according to the viewpoint of the many players, be considered as progress or regression; what is relevant for one can be considered by the other as inopportune, even disastrous. So there is no question of looking here for an illusory consensus on the types of desirable innovations or ideal farming systems. We propose you consider that it is necessary:

1. To prepare a diversity of solutions, to leave the choice to the players, and to be able to confront different futures.
2. To make it easier to anticipate the economic, social and environmental effects of innovations, and more widely, the consequences of their emergence and dissemination on the development of agriculture and territories. The challenge is to be able to appreciate rapidly not only what we hope to gain, but also what we risk losing.

The systemic effects of innovation

Resolving tensions and reconciling the contradictory requirements we have just mentioned will suppose that compromises are reached. In particular, new best practices will have to be sought for the use of inputs, and processes until now neglected will have to be mobilised within the agro-ecosystem (for example, several complementary species in the same field, the activity of macro-fauna in the soil, or interactions between the cultivated field and its edges), or the solution to contradictions insoluble at a given scale will have to be sought at other scales. Technological innovations (reproductive techniques, feed adjustments, veterinary products, aid to decision-taking tools…) will certainly have a role to play. However, simple (even simplistic) ways of thinking of the type 'a problem to solve, a technological innovation to solve it' have shown their limitations.

The case of pesticides is a perfect example of this. In Western Europe, in the 1970s and 1980s, people involved in agriculture, as a whole, lived with the illusion that pesticides would solve all problems of disease, pests or weeds. As other techniques no longer have authority to prevent these problems, they have seen their ways of thinking develop: to favour the expression of the production potential of crops and/or reduce working times, they have changed rotations, sowing dates, densities, the management of nitrogen or water, and methods of working the soil, and these actions are sometimes favourable to crop enemies. Thus, the systems became increasingly specialised on the most profitable species, which has increased the pressure of parasites and created a dependence on pesticides. For winter cereals, farmers brought forward the sowing dates, increased densities and doses of nitrogen fertiliser, and chose the most productive varieties (under-valuing resistance to diseases). All these evolutions are favourable to productivity, but equally to fungal diseases, pests and weeds: intensive cereal crops are very productive but, by construction, very demanding in pesticide treatments (Meynard and Girardin, 1991). So from technological innovations that were supposed to solve precise problems, pesticides became the pivots of production systems. We can now see the agronomic, environmental and health limitations of the immoderate use of pesticides. But it will only be possible to reduce their use significantly if we act on the whole of the crop system, to reduce at the same time the risks associated with bio-aggressors. Generally speaking, the strong coherence which governs farmers' technical choices, as much as the complexity of agro-ecosystem regulations, *invite us to think and act in a systemic way (Gibon* et al.*, 1999): to take into account the unintentional effects of technical choices, to consider the interactions between techniques, to reason by integrating several space and time scales, to consider the herd and the territory it uses as an ecosystem which must be well managed for production to be taken from it.*

The technical choices can also involve not inconsiderable social consequences, although, they are not usually anticipated by those who implement them, in particular for work organization (Madelrieux *et al.,* 2006). We will take the example of the mechanisation of milking, an innovation in principle useful for everyone and offering possibilities of simplification and reduction of work as well as movements (which allows farmers to take holidays). This innovation first of all poses the question of developing skills: setting the machine, disinfecting the equipment… but its adoption also supposes that it is accompanied by generalised electrification in the countryside. Failing which, setting it up can contribute to the rapid disappearance of farms unable to equip themselves with a milking machine, who are gradually marginalised and cannot find a buyer.

Similar issues of this type can be identified for the implementation of artificial insemination. Generally speaking, we must not forget to be careful to check the conditions required for an innovation, and its consequences in the diversity of situations encountered.

Developing the farming world's capacities for innovation

Research work in social sciences teaches us that innovation is not a linear process, with successive stages of research, design, development, production, and finally marketing. It results from permanent comings and goings between these 'stages': it is a collective and interactive process. The sources of innovation are potentially multiple; in fact, the innovations will sometimes be able to originate in research bodies, sometimes in development organisations, sometimes with farmers, but in all cases, the conjugation of the efforts of all will be necessary to consolidate the initial concept, to adapt it to the diversity of environments and farms, and determine its area of validity…

Organising processes of innovative design

Researchers in management sciences (Le Masson *et al.,* 2006) show that developing the innovation capacities of a structure or a collective requires its design activities to be organised and managed. Design is an active, intentional process, which simultaneously generates concepts and knowledge, in order to lead to new products and new technologies. But there is no one-to-one link between design and innovation, and every design is not necessarily innovative. In this respect, researchers in management operate a distinction between two design systems: regulated design and innovative design. In regulated design, which is the most frequent by far, the design objectives are clearly defined in advance and aim at gradual modifications to products or existing technologies. The skills necessary to innovate and the validation processes (prototypes, trials, tests, and indicators) remain unchanged from one innovation to another. This stability allows for the large-scale deployment of standardised working methods, and favours a clear division of work between research and development. In the field of livestock, regulated design could be illustrated by the essential of animal selection; or by the progressive improvement, over 30 years, in calculating livestock feed rations from feed value tables and an estimate of animal requirements.

However, regulated design is no longer suitable as soon as the design objectives are called into question (for example in agriculture by the emergence of new environmental or societal objectives), and because of this, new skills must be mobilised and validation methods revised. *So the term innovative design is used to indicate a process of exploration where it is not possible to specify in advance, the objectives, the required skills and the validation methods.*

The driving forces of agricultural development mentioned above clearly call for a considerable effort of innovative design. For example, the internalisation of environmental impacts in the design of crop and livestock systems does indeed constitute the source of a major change in evaluation methods: Evaluation scales now concern the catchment area or the landscape. In the same way, adaptation to climatic change will involve innovative design work: in fact, it calls into question the references of livestock farmers and advisors, questioning the relevance of know-how acquired in the past. To rebuild their capacity to project themselves into the future, farmers and advisors must combine knowledge acquired in their working territories and knowledge gained from climatic and agro-ecological models.

Work on the organisation of innovative design in firms shows that although the design must be closely linked both to research and to development, it must not be pledged to either of them. Two symmetrical obstacles can restrain innovative design:

- The idea, still shared by many researchers, that innovation comes naturally from the progress of knowledge. Experience of innovative design in the industrial field shows that the design activity must direct at least partially the acquisition of knowledge.
- The choice of many people in charge of agricultural development to work solely on systems which could be immediately profitable, under current technical and economic conditions. This choice curbs the exploration of potentially interesting systems.

To develop the design approach in crop and farming systems

Although, as in industry, regulated design in agriculture is widely practised and well controlled, innovative design will not be able to develop without a renewal of methods: how to integrate new objectives, define new knowledge to be incorporated into the innovation process, and reconfigure evaluation methods in a systemic approach (Donatelli *et al.,* 2007)? A review of the scientific literature leads to dividing the approaches into two large groups:

- The first group attempts *to improve the existing systems step by step*, to adapt them to the new objectives. The design work begins with a diagnosis: in what way do the present livestock or cropping systems satisfy old and new objectives? The diagnosis indicates the criteria which do not obtain a satisfactory result, the agronomic and ecosystemic functions which are in question and technical actions which should be changed to exploit these functions. On the basis of this diagnosis, evolutions of the farming systems are imagined, and implemented. Then a new diagnosis is made, new evolutions of the systems follow, etc. thus engaging in a true spiral of continuous improvement (Meynard *et al.,* 2002). These actions benefit from progress made in recent years in systemic analysis methods in situ, which make it easy to carry out precise and reliable diagnoses (Doré *et al.,* 1997; Doré *et al.,* 2006).
- The second group of approaches aims at opening the field of possibilities. The design of farming systems is based on functional models of crops, herds or farms (see for example Keating and McCown, 2001; Ingrand *et al.,* 2002; Loyce *et al.,* 2002; Duru and Hubert, 2003; De Wit *et al.,* 1988). These models are finalised representations of complex systems which include not only the plants or animals of interest, but also the living organisms associated with them, the climatic and edaphic environment, and all the human actions which apply to these various entities. Such models give a dynamic simulation of the performances of crops, herds and farms subjected to various technical and economic choices, by continuously simulating many variables (virtual experimentation). They predict the long term effects which are difficult to access by experimentation or observation, and integrate the effects of climatic variations (extreme years, climatic change …). By using these models as a base, we can thus (1) identify, within the multitude of possible combinations, the technical acts that respect predefined requirements on criteria of production, costs, margins, work, and environmental impacts; but also (2) analyse the systemic consequences of the adoption of exogenic technological innovations, such as new varieties or livestock farming methods.

These 2 approaches are, in fact, complementary: model-assisted design is better suited to exploring systems that are breaking down, and analysing on computer their long-term risks or consequences, before they are actually implemented. Researchers are fond of this approach, which makes good use of scientific knowledge, synthesized by the models. Step-by-step design is more favourable to learning and moderate risk-taking; because of this, it lends itself better to progressive mobilisation of the farmers, and therefore to development approaches. The learning processes are here a condition and not just a consequence of the innovation process.

Favouring collective learning, to innovate at territory level

How can innovations relating to the coordination of farming systems at territory level be helped? This question often arises, for example about structures for product qualification (Geographical Indications for example), or for the collective management of remarkable environmental resources (irrigated perimeter, natural reserve).

But, now, it is also posed in ordinary rural areas where generalised coordination structures are imposed for traceability, crop protection or the prevention of risks (erosion…). It is a complex question, because the interests of the various players can be contradictory, their representations of the situation irreconcilable, or their information asymmetrical. Some cannot draw any benefit from a coordination of productive systems, or not perceive the benefits they could receive. The already existing networks of players can hinder (but also sometimes help) innovative coordination… Such questions are a special area of participatory research, which is particularly favourable to the analysis of learning processes, individual and collective, which accompany construction of standards, and the evolution of farming systems.

Among the participatory methods, 'Integrated assessment' (Bland, 1999; Pahl-Wostl, 2005) and Companion modelling (Collectif ComMod, 2004) are based on the use of computer models as mediator between scientists and stakeholders. Simulating the expected evolutions of the system according to constraints which are applied to it is a great source of learning. Comparisons of scenarios, debates and dialogues are organised around the results of the model, which lead to improving the scenarios, and favouring convergences between the stakeholders. The modelling of support and guidance is in the same group of methods, used for the collective management of territories with environmental issues. The model, of the Multi-Agent type, is constructed with the users, developing both their knowledge and that of the scientists. A role play, based on the model, makes it possible for the players to share their representations, without necessarily making them converge towards a single representation, thus favouring discussions on their actions or projected actions.

Conclusion

Innovative design must mobilize a collective and distributed intelligence, more effective, faster and less hazardous than individual approaches, that are dependent on dominant discipline or local representations (Lançon *et al.,* 2008). This supposes the organisation of complementarities and an increase in communication between the various players in the innovation: researchers and R&D engineers (collectives, largely represented in this symposium); farmers and breeders; the authorities…

The development of innovative design thus begins by inviting researchers and R&D engineers to use their expertise, their collaborations, and their practices. This evolution is illustrated by animal production research in livestock systems (Dedieu *et al.,* 2008). Until the mid-nineties, research at international level was above all situated at the interface with physiology (animal and plant) and genetics, leading to innovations relating to the methods of calculating feed rations, directing reproduction or evaluating breeding values. Today, research has explicitly moved towards interfaces with ecology (ecological management of grasslands and rangelands, soils and landscapes), and social sciences (methods of participative design for innovative systems, socio-technical systems). To successfully conclude this change, livestock farming system studies have a major asset: it is at the same time (1) a scientific discipline which produces generic knowledge, taught and shared with an international community, and (2) an engineering composed of a multitude of know-how controlled and perfected by livestock farming system experts engaged in the action.

Far from isolating research in its improvements, we must collectively recognize the major role played now and in the future by farmers in the design and development of innovative farming systems. Our job is to identify the key innovations for the future, analysing them, evaluating them, and suggesting adjustments to widen their field of validity. But it is also to develop co-design processes where the complementarity of various types of know-how is placed at the service of a joint project.

Finally, the authorities can play an important role in stimulating the design of innovative systems and their development: they must ask themselves how to encourage agro-supply companies to be involved in the collective activities of design (Aggeri, 2000), how to encourage a growing number of advisers, livestock farmers and researchers to become involved in these activities. To act on economic and social dynamics of great inertia, such as those which govern farming systems, will suppose consistency in the messages addressed to the people concerned, consistency of public policies and transparency in the evolution of regulations: isn't one of the obstacles to the development of sustainable farming the fact that public policies are not themselves sustainable?

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