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Integration of Bio-technical, Economic and Social Sciences

INRA-SAD research experience regarding technical systems in farming, rural development and natural resource management

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Introduction

For the forty-year period immediately following World War II, during which the rural world experienced profound economic and social upheaval, a gap became increasingly apparent between the extremely diverse needs of farmers and the recommendations and technical advice offered by agricultural research and extension. This gap was indicative of the inadequacy of extension and development structures (less than one quarter of farmers were affected by development projects for example) when confronted with new social issues (such as water source protection, prevention of forest fires, etc.) and with the limits of the techniques proposed in the areas for which they were intended (such as cereal or dairy basins) or with the marginalisation of other areas by technical progress itself.

In order to understand this increasing divergence and thus help to remedy the situation, INRA decided in 1979 to create an interdisciplinary department for research into Agrarian Systems and Development (hereafter referred to as SAD). This initiative followed a decade of multidisciplinary research programmes on rural development and land management commissioned by the French government and involving several large research institutions. After fifteen years of research in the field, in a wide variety of situations, we propose to describe this experience and outline the main features which marked the construction of a research field exploring farming and rural activities, and which serve to identify our department[1].

This new INRA department was gradually built up by researchers in quest of other disciplines in order to understand the technical needs of farmers and the local interests involved in rural development. This quest has led to a close association between technical disciplines and social sciences, and parity between these disciplines has been established mostly by undertaking joint projects on technical systems. We feel that the difficulty inherent to this interdisciplinary collaboration is partly responsible for the current criticism levelled at systems research in developing countries, even though this type of research is expanding in industrialised countries, as will be illustrated in the third section of this paper. We are of the opinion that systems research has an essential role to play in dealing with the challenges

[1] The research department for Agrarian Systems and Development (INRA-SAD) currently employs 200 staff, including 80 researchers.

confronting society today; and one of the conditions of the success of systems research resides in the pivotal issue of actor-group training within the processes of research and action.

Researchers in quest of other disciplines

Unsatisfactory implication of researchers in action; shaping a course for an interdisciplinary approach

Researchers confronted with actor-group decision-making and practices, using tools emanating from disciplines concerned with dissecting reality, have not been in a position to apprehend the multiple consequences of decisions made by farmers and the systems in which their research involved them. Thus, other disciplines have been called on, either those taught in schools of agriculture (economics, agronomy, livestock research, etc.), or sometimes more independent such as ethnology, anthropology, ecology, etc., and researchers have found themselves out of their depth working on difficult and complex subjects such as the farm or the agrarian system. Clearly, the most serious drawbacks of disciplinary barriers occur in the domain of action, since action involves several disciplines. The various researchers working on agriculture have their domains of competence and their analysis tools defined by scientific concepts and methods that are out of touch with the actual practices used by farmers. Does the answer lie in calling upon people capable of synthesizing or "adding together" the various results available in order to implement or encourage action in a specific domain? Since they possess knowledge in a variety of relevant domains, they are undoubtedly useful, but "synthesis has limits of its own in that the simple addition of specific areas of knowledge can miss the vital point when used in real situations" (Gras et al., 1988). The systems approach puts the emphasis on interaction and interfaces, on the project underlying the action, and allows functioning, thus the overall management of the project under study, to be apprehended.

Our systems research is objective-oriented, since it is initiated by problems that come up in the course of action and aims towards innovation. It is the result of a wide-ranging management project that is difficult to "disciplinize". This systems research designed for action is actuated by the analysis of concrete problems because it is connected with a direct social demand, entailing a specific type of methodology : action-research[2]. It is also based on the following epistemological postulate, which is vital to the method of enquiry used by the SAD, i.e. all action affecting reality is also a means for understanding reality (knowledge acquired in action). In addition, the objective to understand what every action implies, motivates and upsets, in other words the cognitive project, is also important. As Michel SŽbillotte pointed out at the symposium on agrarian systems in Montpellier (1994), "prior to action, a perception of reality is necessary which links up the action variables with objectives, which establishes priorities amongst these variables and which supplies indicators for action initiation over the course of time."

[2] In action-research or participatory research, the researchers are not external to the system under study and the operational parties take part in the research. The object of this paper is not to develop this methodology which is explained in Vallerand, 1994; Brossier, Chia, 1994; and Albaladejo and Casabianca, 1996.

Types of collaboration between disciplines

In INRA-SAD experience, collaboration between biotechnical sciences and social sciences began originally on the farm level. This can be illustrated by identifying three types of collaboration between economists and scientific researchers[3].

1. First of all, the utilitarian request for technical information. This works both ways : the economists ask the technical researchers for technical coefficients to include in their models, the technical researchers ask the economists to calculate the value of a Forage Unit (FU). Examples are plentiful, we need go no further. It should be pointed out that this collaboration, which cannot be called multidisciplinary since no effort for mutual reflection is made, is often a source of incomprehension: what exactly is a good technical coefficient? What is the economic value of the FU? These incomprehensions increase as the research work distances itself from research for theoretical norms or laboratory norms and concentrates instead on what really happens in farms.

2. At the second stage (towards multidisciplinary research?), mutual reflection and dialogue exist; meaning that the mutual questions being posed can be specified. Each researcher goes along with the theory of the expert of another discipline in order to understand the nature of the questions being posed in each discipline and why the answer to a specific question (technical coefficient, FU value) is not as simple as it seems. Several examples of multidisciplinary collaboration can be described, one of the first being: Research into production systems used in industrial-crop areas at the end of the 1960s (Brossier et al, 1974).

3. The third stage (towards interdisciplinary research?[4]) could be the creation of a common scientific field between experts thus achieving parity between disciplines. This parity concept requires explanation.

Achievement of parity between disciplines

Firstly, mention must be made of the initial incomprehension and concurrent investigations that underlined the need for achieving parity between researchers in different disciplines. This parity cannot be decreed, but is built up over time. It requires a real commitment on the part of social science researchers and technical researchers to work on management problems which need to be studied in the overall farm context.

The demand for multidisciplinary research was mainly initiated at INRA and in Higher Schools of Agriculture (les Grandes Ecoles) during the 1970s by researchers in biotechnical sciences. They felt that the traditional research approaches were a poor answer to certain fundamental development questions. They were dissatisfied with the increasing gap between the specialised technical propositions of individual fields of research, in theory effective and efficient for farmers, and the conditions and actual levels of adoption of these techniques by

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[3] One of the authors of this paper is an economist, which explains the use of certain examples of collaboration between economists and technical researchers.

[4] We agree with Couty in that the aim of interdisciplinarity is to “ try to make the cognitive fields of different methods overlap, thus progressively creating a new field which is common to several disciplines ”. In the rest of this text we use the terms multi- and inter- in their meanings here..

the farmers in their specific situations. This gap led (and still leads) to inadequate extension, which only concerned a limited percentage of farmers. These researchers held that a conceptual detour was necessary, aimed at studying farm functioning (considering the farm as an entity and accepting the consequences) and agrarian systems, and aimed at enlarging their various methods in the light of this analysis. This preoccupation made them turn towards and collaborate with economists who considered the farm as an entity. This collaboration paved the way for the creation of the SAD.

Studying farmers' management practices and decision-making obviously involves interest in techniques but even more in practices, and certain researchers in agronomy were the first to recognize this. This was an important step forward, and worth mentioning, since it enabled parity to be built up between the social sciences and the biotechnical sciences (cf. Teissier, 1979; Deffontaines and Petit, 1985; Landais and Deffontaines, 1989). If unidimensional grasp of a problem is considered to be sufficient (in a technical field for example), one cannot go beyond remarking a certain disorder difficult to explain except by appraisals such as "routine, out-of-date, trivial"[5]. Such explanations are not satisfactory to researchers since they explain nothing and are not useful for action.

On the other hand, the concept of technical skill means the interconnection of two necessary aspects of agricultural activity: on one hand the consequences of a technical activity involving the soil, plant cover, or livestock, and on the other the determining factors for implementation on the farm. This concept is on the cusp between the physical environment and the socio-economic environment[6] (Gras et al, 1989; Latour Lemonnier, 1994). Agronomists lost no time in considering agronomy to be a " social science " as well, providing a wide opening for dialogue with the other social sciences. By giving precedence to the point of view ("the point of view creates the subject " cf. Osty and Landais, 1994[7]), agronomists were able to demonstrate that a number of different scientific viewpoints existed, thus facilitating the idea of agronomy as a science distinct from a certain number of neighbouring sciences (soil sciences, biochemistry, plant breeding, etc.). Thus, taking the example of plant nutrition, Soil Science studies the soil as a "source" of nutritive elements, and Agronomy studies the "resource" utilised by the farmer (Bonnemaire, 1987).

On their side, the economists, representing the "homo economicus" approach to decision-making, considered and indeed still consider themselves as experts capable of synthesis on the farm level, but these syntheses are highly influenced by limiting hypotheses made at the outset. These economists tend to appropriate technical research and are often perceived as imposing their point of view. Initial collaborations with technical disciplines, although they were and still are utilitarian, caused economists to change their outlook, especially in the area of farmer relations. The methods used by technical researchers working on physical flows (milk, wheat, etc.) entering into closer dialogue with the farmers regarding their practices, have incited economists to stop working solely with traditional economic flows (bookkeeping, fiscal or economic flows such as farming revenue or depreciation) based on principles the

[5] There are a multitude of examples of decisions made by farmers and qualified as irrational because they are not coherent with certain technical or economic norms (work simplification, imitation, prestige, attachment to the land). Is it possible to understand behaviour that one qualifies as irrational?
[6] We refer to research fields opened up by the work of Leroi-Gourhan on techniques considered to be interfaces of society and their environments, and thus used as proof of evolution over time and of the diversity of continually transforming environments.
[7] "Each point of view is a result of facts, mobilises specific methods and tools, proposes a logical answer to observed or expected phenomena" (Auricoste et al., 1983)

coherence of which was totally different from actual farm functioning. It became essential for management economists to work on identifiable flows as well (cash flow and monetary flows). Although this is not always easy, by focusing on the economic practices and especially the cash flow practices used by farmers, management economists can also achieve parity with technical researchers studying the formation and chronological planning of other identifiable physical flows, (Chia, 1987; Brossier et al, 1988). Overall study of an individual farm can then be made collectively. The collective nature of this study must be underlined, and can even be considered as characteristic of the elaboration and functioning process particular to the systems approach, since it also embraces the social actor-groups that are both subjects of and participants in the research.

Problems of interdisciplinarity and parity specifically connected with economics

Economists are well aware that non-economist colleagues with whom they work also have their points of view as ordinary citizens on economic issues and the social debate. Even if the majority of economic subjects are specific to this science, it is true that some of its main subjects, such as the definition of decision-maker objectives, farmer revenues, economic relationships between actor-groups, are dear to the hearts of citizens, and economists are expected to give guidance on the choices made by decision-makers and therefore citizens. Economics makes a contribution to this even if it is evident that these choices are not completely objective, since this is never possible. One can see why the boundaries with idealogical issues connected with the social debate are not always very clear. The specificity of economics lies mainly in how these issues are dealt with, thus on the level of methods.

It is important to keep in mind this economic questioning, since it is of concern to both researchers and citizens, in order to understand the collaboration between social sciences and biotechnical sciences in systems research. This questioning creates difficulties in communication taking the form of queries on the part of technical researchers, which are difficult for economists to accept, but which are essential to research which directly associates the various social actor-groups. This point also goes to explain why economists in systems research teams have certain doubts with regard to their science

Most economist researchers involved in this systems science adventure are clearly not satisfied with certain hypotheses and principles of economic theory, particularly the production theory. It is true to say that this theory was the first effort to create a model representing producer behaviour, but the research work of several systems teams have shown the limitations of this theory in understanding their behaviour and activity. For these research teams, the company is not only an abstract entity used in the study of supply in microeconomics, but is the subject of and the participant in the research. This research work has resulted in the creation of models such as the theory of adaptative behaviour (Petit, 1981; Brossier et al, 1991) or action models (Attonaty and Soler, 1994).This questioning of methodology is accompanied by doubts relative to the self-interest model considered to be the economic impetus in the theory. It must be said that this theory of individualism freed man in the past from alienating conceptions, which prevented individual action. There is more to man than his own selfishness, and the self-interest of economic actor-groups[8]. The economist R. Frank (Frank, 1988) calls the Self-Interest Model (SIM) into question and puts forward the

[8] This theory is alienating in itself, because by " encouraging us to expect the worse of others, it brings out the worst in us " (Frank, 1988).

hypothesis that the emotional predisposition to behave in an altruistic way can be of advantage to the individual. The SIM does not explain the existence and proliferation of charities for example, nor that a small shopkeeper belongs to a union which in all probability can offer little support, nor that it is in our interest to behave honestly.[9] R. Frank proposes the Commitment Model (CM) in order to explain that what can appear to be irrational behaviour is in fact a result of emotional predispositions, which help to solve this apparent contradiction. The Commitment Model underlines the role of emotions in behaviour, and is based on the principle that altruistic behaviour is controlled by the emotions and not by cognition. The CM suggests that it is useful for the individual to appear honest in society and that the best and most reliable solution is to actually behave in an honest way.

This criticism of the SIM is important in agrarian systems modelling, which focuses on collective projects. Andre Brun (1995) holds that citizenship today can be understood as being less individualistic or more supportive of collective values and constraints, or to speak in more positive terms, as participation in projects the advantages of which are not measured by the individual interests to be gained but by the collective well-being and reduction in inequality that they engender: "common causes" can lead to the voluntary subordination of individual interest to collective well-being. The local context and decentralisation are not the sole ways of restoring a weakened sense of citizenship, but the general trend leading to greater local autonomy (through decentralisation and subsidiarity) is a golden opportunity for creating at each elementary level a "common cause" which tends to be lacking in society as a whole.

Parity, training of researchers in Higher Schools of Agriculture, and development of systems research in France

It is our opinion that the longstanding development of systems research in France and the relative expansion of multidisciplinary research, both of which led to the creation of the SAD Department of INRA in 1979, should be connected with the fact that the first generation of systems researchers were mainly graduates from the Higher Schools of Agriculture (Grandes Ecoles) so specific to France. As per the French system, all the agronomists of the 1950s, 1960s and 1970s received background in three disciplines that are fundamental in studying production systems and agrarian systems, and all of which are central to the SAD department (livestock research, agronomy, economics).

This made multidisciplinarity easier since based on a common culture and language, thereby facilitating joint research operations[10]. This does not go to say that the French educational methods should be extended outside France in order to ensure the development of systems research. Actually, the model is dated because, firstly, multidisciplinarity is highly limited to the three disciplines mentioned above which is obviously insufficient for drawing up a systems science blueprint, and secondly, both in France and elsewhere attention is being

[9] The Self-Interest Model is based on the principle that when there is no risk of vengeance, it is best to be a "free-rider" even though people do not all behave in this way. For those who accept the free-rider hypothesis (as the number of potential contributors grows, the amount each person will voluntarily contribute shrinks) the notion of a voluntary public good is an oxymoron. Numerous tests have been carried out and they do not show, as the SIM claims, that all the participants in the test display free-rider behaviour and in fact these tests prove the contrary to be true (Frank, 1988).

[10] Let us point out that in France, multidisciplinary and systems research other than in agriculture is often initiated in the Higher Schools of Management (Grandes Ecoles d'Ingenieurs : Ecole Polytechnique, Ecole des Mines) or by graduates of these schools.

drawn to insufficient training in multi- and inter-disciplinary approaches, and the fact that systems science and constructivist epistemologies are having difficulty penetrating university circles (hence a workship on the subject of training, initiated at the Montpellier symposium and organised once more at this second European symposium in Granada).

The role of models in interdisciplinary and systems research work

It is worth mentioning the positive effects of modelling and the models actually built thanks to this search for collaboration between disciplines. J.L. Le Moigne points out (1990) that modelling can be analytical (cartesian) or systemic. It is systemic if the actions and interactions are intentionally modelled as a project, the teleological project of the person responsible for the model being essential to it. Le Moigne says for example that "modelling a company means modelling a complex set of actions that are intelligible compared to company objectives in an environment within which it functions and changes" (Le Moigne, 1987). This idea is taken up by Barry Dent (Dent, 1995), for whom the main function of soft systems models is to create debate and discussion about an agreed area in development, by providing indicators that describe possible outcomes of alternative actions.

Usually, the information relative to other disciplines requested by people responsible for creating models is often utilitarian, and this is an example of the first type of collaboration presented above : research for technical coefficients to include in a model created by an expert in a specific discipline. Economists are used to this. The task of formulating models is a process that becomes systemic only when projects and intentions need to be represented from an interdisciplinary angle. The joint effort involved in building a collective model goes beyond utilitarian requests and creates congruence between researchers of different disciplines. In this type of context, a model is a simplified and ephemeral image of a system-project which is in the process of being built.

It obviously has its formal rules which must be accepted by the partners in that these rules contribute to carrying out the project. Interpenetration of the different disciplines represented by the partners involved in the operation is a necessary condition for the success of the undertaking. This interpenetration takes the form of on-going dialogue between researchers so that they are aware of the latest developments in the other disciplines, including the nature of the technical questions that are being posed. Congruence is at its peak when each researcher is aware of the limits of the hypotheses put forward in his discipline thus implying respect for the other disciplines and the work that is jointly elaborated. This leads to feedback, deeper investigations and to the disciplines being called into question[11]. Modelling using mapping in rural development research and in actor-group training is a convincing example of the value of systems approach modelling (Deffontaines and Lardon, 1994). Another example of modelling is outlined below, relative to research into the relationships between a mineral water company (MW) and a number of farmers working in its vicinity (1990-1995)[12].

This research consisted of collaboration between agronomists, economists, and extensionists, several farmers and the company for building and analysing farm models. This was a question

[11] One of the difficulties of interdisciplinary debate, as Michel SŽbillotte points out, is without a doubt the viewpoint held by each individual as regards other disciplines (and even his own), since it is often shortsighted and old-fashioned.

[12] For further details concerning this research project on the development of sustainable and environment-friendly agriculture, see Deffontaines et al., 1994 and Brossier, Chia, 1994.

of simulating the nitrates constraint in the farms concerned, of defining new adapted production systems, of studying the consequences of the changes proposed regarding farm functioning and profitability, and of suggesting possible terms of negotiation between MW and the farmers. The models (linear programming models) incorporate the data available concerning the harmful effects of certain farming practices, they indicate the practices that should be used and give information on them. The models thus built have enabled pertinent questions to be posed as to the nature of the nitrates constraint and what this means to the farm (role of dairy-cow grazing for example). Feedback to the disciplines leading to their enrichment (decision-making concept, production function, management theories, etc) clearly is one valuable result of the interdisciplinary project, but there is more. This joint project has had various effects, not least on the modelling process itself, and queries concerning the use in systems science of particular models.

– Management economists have elaborated marginal productivity curves for nitrates based on milligram increase or decrease compared with the nitrates constraint (see Figure 1)

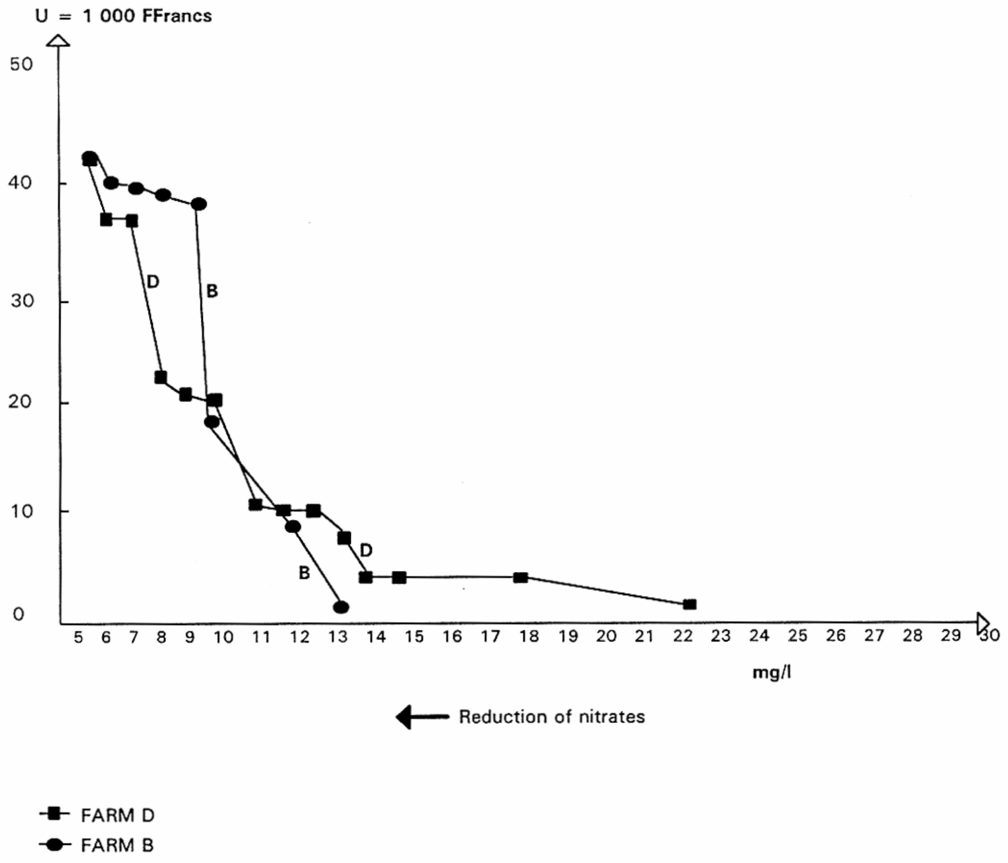


Figure 1: Marginal cost-Marginal productivitiy each MG/L of Nitrates)after technical and economic improvements

– This productivity curve is a typical fruit of the collaboration between agronomists and economists, and is based on the connections between fertilisation practices, N-balance readings per hectare and nitrates loss under the roots measured by porous ceramic cores. At the threshold level requested by MW (10 mg/litre), each milligram drop in nitrates is extremely costly to obtain. There are of course possible technical solutions, but they require considerable improvements in management: drastic changes in production systems, strict crop management, improved development of products.

- On the technical side, results are highly sensitive as regards variations of annual N-balances of crop rotations and of grassland. This sensitivity is connected with the technical models, and thus complementary research has been undertaken in order to shed light on certain grey areas, such as the major polluting effect of dairy-cow pens. This in its turn brings up problems connected with farm functioning, since it is important to improve the management of pastureland either through changing the plot plan (increase the size of dairy-cow pens and thus diminish the number of dairy cows per hectare) or through different herd management techniques (bringing in the animals at night, zero-grazing).

- Models elaborated jointly by the various researchers and with farmers have been used in a wider approach to systems modelling. The object of this was to open up the field of negotiations between the different actor-groups (participatory approach or action-research). Using images furnished by the current situation and possible future open situations that are sufficiently credible, discussions concerning the sensitivity of results situated the challenges involved and the aspects requiring clarification, thereby establishing a list of priorities that remains an open issue. From a concrete point of view, the debate between the farmers, MW and the researchers, set off by the marginal cost curve of the nitrates constraint and the constraint threshold has underlined the interests at stake in the negotiations between the farmers and the company: scope of change expected of the farmers, level of support that the company must/can contribute, etc. In this case, using this model as a dialogue tool, the results are less important than the preparatory work for defining the model, than actor-group participation, and than the discussion that these results engendered. The difficulty inherent to this time-consuming approach should not be minimised, because the means proposed by research to facilitate dialogue are often inopportune, and this was true of the MW project where not all of the farmers participated in the process.

Systems research: objective-oriented and conducive to relationships between researchers and other actor-groups

This MW research example demonstrates the relevance of the model-building hypothesis of systems science. To deal with the complex issue raised by MW and the farmers, we propose the hypothesis of a system intended to reduce nitrates whilst developing efficient agriculture. Study and monitoring of this elaboration process require tools and methods which, although not unusual in research, imply the interconnection of several disciplinary points of view and of several levels of investigation (see Figure n° 2): from the porous ceramic cores to the development of "clean" farm products and to action-research that involves actor-groups and researchers in the process of knowledge elaboration and changes, the MW research project has numerous facets requiring interconnection. Given the interests, often contradictory, of the various partners involved, this implies acceptance to adapt and even to manage the research as it comes. The contribution of research is not to solve an incompletely identified problem: prevent the increase of nitrates in water bodies, even though this has been requested, but to help the problem to be properly formulated (problem finding): where do the nitrates come from, who is responsible for the increase, which practices need modifying? (Simon in Newell and Simon, 1972). The solution cannot be "invented" by the research, it is produced collectively thanks to the creation of new relationships and organisational innovations connecting the actor-groups and grouping them together. These innovations are not easy to achieve because they relate to a multitude of endogenous and evolutive projects.

Research subjects investigating technical systems

In this perspective of research objectives oriented towards development, which is examined using the study of technical change, we have been involved in constructing specific research subjects covering both technical and social aspects. Techniques are at the core of these constructions which imply a certain choice of theory, resulting in a specific methodological approach that will be detailed below before illustrating our remarks with a few examples of research subjects examined.

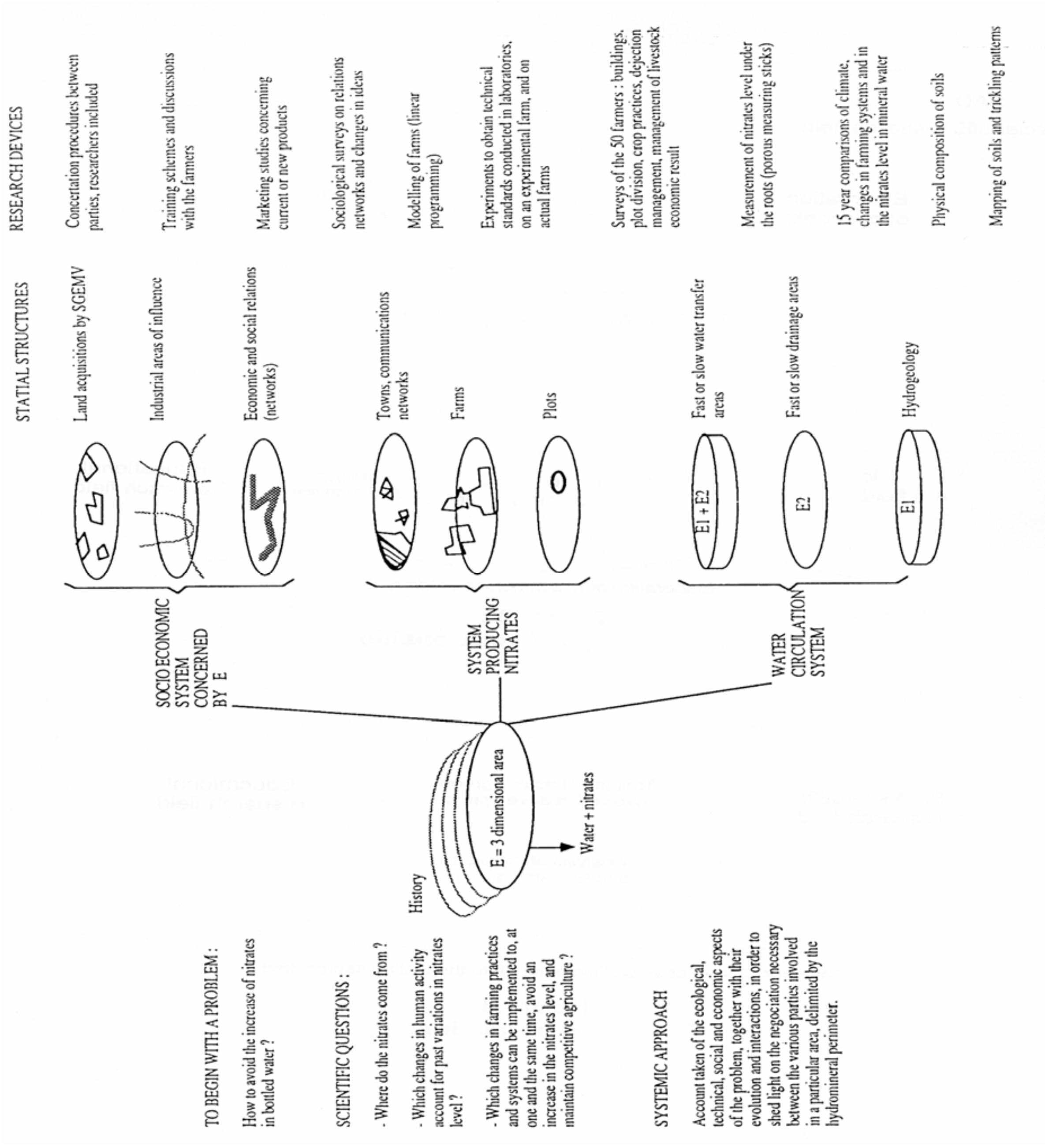


Figure 2: Structure of the interdiciplinary research programme

Theoretical principles

Research subjects relevant for action....

We have become interested in technical systems for two reasons:

– they are action systems, elaborated by social groups to affect the world; which means that they are particularly relevant subjects for our research;

– for their theoretical side: technical systems are central to the relationships between social groups and the physical or biological domains in which these groups wish to act, and have at once social, symbolic and physical sides. Thus study of technical systems enables these different dimensions of human activity to be examined simultaneously, especially relationships between culture and nature.

We are of the opinion that action and knowledge should not be separate from one another: training acquired in action produces and organises the knowledge held by individuals within their social group, or in contact with other groups, or with other types of knowledge; conversely by "producing knowledge" as researchers tend to do, they are also involved in action, by contributing to the creation of a certain perception of aspects of nature or societies, using modelling and developing choices of techniques. Relationships between these different forms of knowledge - held by farmers, by technicians, by researchers - assume vital importance in research into the processes behind innovation, whether this be technical and/or organisational, and into the paths taken by farmers and development backup structures in adapting to technical, economic and social changes.

.... because they are elaborated by social groups

Interdisciplinarity is necessary to the study of technical systems due to the separation of sciences into distinct fields of knowledge, as opposed to the knowledge emanating from action. Thus, this is nearer to technological science[13] which presents itself as a research field calling upon physics and biology, technical sciences and social sciences. Technology gives new scope to the usual multidisciplinary methods, as these methods are more often than not based on grouping biology and economics; as Worster points out (1977), in most sustainable development models, findings are frequently borrowed between ecology and economics, both of which present themselves as complex systems sciences: interdependencies of human beings and living organisms, division of work, allocation of time and energy, competition between species, consumer notion, use in ecology of certain traditional micro-economic models (cf. predator-prey models), etc. But these models, often used in connection with renewable natural resource management, stumble from an operational point of view in real situations involving the management of living organisms by social groups, who develop technologies that are not just simply sequences for optimising kilocalories, or even monetary values[14].

[13] As defined by ethnologists of the French and Anglo-Saxon schools such as Leroi-Gourhan, Haudricourt, Creswell, Conklin, Ingold.
[14] See for example the global model built by Meadows (Meadows et al., 1992).

Between the sphere of aspects of nature studied by the biological sciences and that of aspects studied by traditional economics, a whole field has been neglected relative to the organisation of social groups in their environment. Within this field we give high priority to the study of technical systems that are created for the development of these groups, and thus undergoing constant change. Different approaches need to be developed before information can be forthcoming. Thus, disciplines such as anthropology, sociology, management, closely collaborate with biological disciplines (ecology, genetics) and technical disciplines (agronomy, livestock research) in the study of "hybrid" or "borderline" subjects which also have meaning for the farmers and technicians with whom we work. Innovation processes can then be examined in the context of technical change. These are processes of social transformation incorporating technological inventions and ideas borrowed from technology; they cover both the techniques themselves and their conditions of implementation in organised or organising systems. Their study concerns at once biophysical matter (soils, plants, animals) and the social organisation of rural societies which is why the different disciplines are aware that their mutual interests lie here. In our view, this is also why technological innovation includes technical dimensions plus organisational dimensions; these two dimensions can be apprehended on the farm level in the production processes themselves, or as regards the local economic and social fabric in the relationships between social groups, in the new perceptions that are created and in the dynamics of knowledge and know-how.

But the research subjects are no longer those studied in monodisciplinary contexts: we study for example the crop systems used in a field pattern; organisation of farm shift; herd management; qualification of local farm products (such as cheese, processed meat products,...); path, canal, hedge, and ditch networks or the woods, copses and clearings which make up the landscape; the breeds that social groups identify, specify and demand; pastures that herders categorize in order to improve associations over the day and over the seasons.

A specific methodology

Research in the field

A specific methodology needs to be applied in the case of research in the field, the field consisting of farms and the actual situations with which our partners are confronted, and not the methods used by laboratory experimentation nor statistical interpretation based on a different logic. Although some of the research is based on direct observation of events, interviews are nonetheless essential in design of our studies, which are put together and implemented with all the usual rigour of scientific method thus ensuring the validity and reliability of the information gathered.

This situation is not conventional, as is confirmed by all the sociological, socio-linguistic and ethnological analyses of this type of confrontation between various schools of thought. Because in the present case, the vision of the world born of scientific thought with which researchers address reality (i.e. in this case the subjects examined by them but also the opinions they listen to) is brought closer to the vision of the world held by each actor-group which determines their action, creating what can be called practice-determined thought. The aim of the interview is no longer limited to providing information to the researcher so that he can feed his own model of reality, but it makes the actor's way of reacting to reality intelligible to the researcher. In other words, the researcher can build himself a behaviour model for farmer action. This consists of clarifying how the farmer, given the context of his practice, poses his own questions and gives his own answers.

For us, this involved examining other types of reasoning (those of the actor-groups with whom we have contact) using a scientific rationale (and the methods and means of validation that are connected with it) with a view not only to observation but also to intervention (cf. Garfinkel, Schutz). As already stated, there is no question of interpreting the action observed as irrational, nor of undertaking detailed investigation in terms of the individual psychology of those responsible for the action; but the point is to make the reasons of other people intelligible.

We are here at the heart of the questions posed by the intersection of several systems of knowledge, brought together in a joint project of problem-solving. The researcher needs to take a certain number of methodological precautions into consideration if he is to avoid falling into two traps: description based on auto-justification which is content to interpret perceptions and idealise them in the name of the legitimate conceptions which underpin them, and prescription for problem-solving which seeks solutions to problems and aims to apply the solutions to those posing the problems, irrespective of their conceptions and systems of standards. Clearly the intersection of, and joint work undertaken by, the social sciences oriented towards understanding systems of thought, and the technical sciences oriented towards evaluation of biotechnical processes, can enable these traps to be avoided, can underline the limits and inertia of practical know-how and can encourage the emergence of acceptable solutions.

Recognising that "farmers have their reasons for doing what they do" must not however lead to the rejection of any transformation, or of any current or potential dynamism: practical knowledge is not at a standstill, training processes are operative on the job (adaptation to climatic and economic uncertainties, etc.) and it is possible to borrow ideas (dialogue and technical exchange networks between farmers and technicians, means of support and technical advice, etc). This leads us to keep our distance from positions such as "methodological individualism" which do not address the social links that make up the fabric of the cultural context in which the individual actors are situated. On the other hand, constructivist sociologies, which emphasise the comprehensive dimensions rather than structural aspects and approaches like those used by technique anthropology, take the social elaboration of these techniques into consideration.

... based on rigorous methodology

The methods we use are based on the observation of practices (i.e. technical acts as they are actually implemented) and on carrying out interviews analysed by speech analysis techniques (particularly in researcher-farmer dialogue situations, J.P. Darre). But we do not consider this outside view to be sufficient, since, even if it completely transforms what we call assessment, it is not thorough enough for technical researchers who are also competent regarding the questions being addressed: knowledge held by farmers and farm advisors certainly has its merits but it is not alone in this respect!

With the help of constructivist and systems approaches, we organise our own elements of scientific knowledge, which are indispensable for transcending actor reasoning and thus forming an outside but legitimate opinion concerning their acts. Does the economic or social behaviour of these actor-groups, and the way they affect physic-chemical or biological processes in the course of technical, economic or social action, allow them to achieve their ends? Do they employ the necessary means? Do they measure and do they control the direct effects and indirect consequences? Keeping this in mind, we conduct our own observations on the processes in question, on which we develop disciplinary points of view that make reference to known theoretical principles and thus to existing indicators for the disciplines concerned. The field of experiment design (J.M. Legay) concerns experimentation in the strict sense of the word as well as quantified observation of the functioning of complex systems, hence the particular attention given to modelling methods, in which the process itself is at least as important as the model finally produced.

The research projects that we conduct with this objective in mind are based jointly on:

- the elaboration of the behaviour model for farmer action, based on observation of his practices and analysis of interviews with him: this stage enables identification of the projects actually managed by farmers, classification of the information that they acquire on these projects, and how they act with respect to these projects;

- the production of scientific knowledge regarding these projects which as a general rule differ from usual research projects: they need to be defined and classified, temporal and spatial dimensions included, after which models of their functioning need to be created, enabling indicators as to how farmers keep themselves informed about the processes underway to be identified, and the effects (and consequences) of farmer action at any given time to be simulated;

- the interpretation in technical terms, and the discussion with our partners about the discrepancies between the referentials based on scientific knowledge and the results and performance observed in the actual situation under study; this is how the farmer's thoughts and acts are confronted with what the researcher thinks the farmer should do: it is this dialogue, in terms of difference of appraisal, and not in terms of confrontation of norms, which enables a truly interactive assessment stage to be entered into, since it is based on the joint identification of the field in question.

Thereafter, practices can be evaluated according the three dimensions proposed by Landais and Deffontaines (1989):

- the means involved: how techniques are put into effect;
- level of efficiency: results obtained
- opportunities or effectiveness: do they achieve the objectives set by the person implementing the practices?

The conjunction of these three viewpoints is required for an evaluation which takes into consideration both scientific knowledge and the conditions in which the observed action is carried out, so that modifications can be envisaged that are scientifically founded and socially relevant. It is clear that close interdisciplinarity is inherent to such an approach.This is the process that we intend to illustrate using a number of specific research projects built on this type of approach.

Examples of "borderline subjects"
Research subjects involving production management on the individual scale

.... livestock management

In connection with research into livestock systems, we have been led to identify the herd as the actual entity managed by livestock farmers, whereas researchers have tended up until now to study the individual animal presenting a series of functions, such as reproduction, nutrition, health, etc. Yet a herd cannot be reduced to the simple addition of the individual animals composing it: it has properties directly resulting from its functioning as a group (initiation of young, interactions in animal hierarchy, spreading pathologies, attitudes towards farmer, etc.) and how it is managed by the farmer (decisions relative to the feeding system, reproduction management, genetically pure or crossed material, prevention of certain diseases; accommodation practices, separations in groups and regrouping, etc.). One herd is thus distinct from another, often primarily because a particular farmer manages it.

We have thus been led to elaborate the scientific terms relative to this new research subject, such as the notion of lifetime performance to describe the temporal itinerary of the animals during their productive lives (Vallerand, 1977; Gibon, 1979; Lasseur and Landais, 1992), or that of the irregular female (Santucci, 1991) and the study of herd parturition curves thus explaining and evaluating production organisation (Girard and Lasseur, 1996), or also that of health performance which for us is inseparable from zootechnical performance in evaluating herd management results. Building on basic knowledge in nutrition, physiology or animal pathology, we have been led to enrich it with new concepts which are more relevant for appraising farmers' practices and thus more apt as a basis for decision-making tools. These approaches have been complemented by specific studies, such as the study of the symbolic value attached to herd reproduction, particularly for sheep farmers involved in industrial crossbreeding (Migliori et al., 1994).

Similar methods were recently developed for studying cropping systems used for plant production, such as farm shift which signifies field pattern organisation over the entire farm acreage, and which is much more than the simple addition of all the farm plots (Aubry, 1995).

... grazing management

We take here the example of animal grazingland feeding. For several years our research work has examined herder know-how and has evaluated performance regarding livestock feeding management (cf. Landais et al., 1993; Meuret, 1993). In the case of grazingland, this know-how is manifest in the conception of the daily grazing route of the herd, associating different portions of land and thus responsible for synergetic feeding sequences during the course of meals. In view of grazingland heterogeneity, the question for farmers is not to single out a few homogeneous good-quality plots when applying the norms contained in forage food-value tables, but on the contrary to make optimum use of spatial variety in terms of appetitive value through the creation of sequences which stimulate appetite with regard to the most abundant, though unrefined, resources, and for which the animals are not naturally enthusiastic.

Bringing back the grazing-route technique does not just consist of going back to practices used in former times: genotypes have changed, production demands are higher and new interests connected with land upkeep have appeared ... (Hubert et al., 1995). Research is working on the conception of spatial rationing models which encourage the ingestion of target vegetation either with a view to controlling a highly invasive dynamic or requiring renewal. The different areas on a grazing route to put in sequence are usually composed of several plant communities and accomplish one of six different roles during the meal: appetizer, moderation, main course, booster, second course, dessert (Meuret, 1995). The quality of the model is achieved by controlling the frequency with which the herd is in contact with new places and resources and with its favourite plants. As shown by the most recent models available for animal nutrition, which centre on the analysis of meal dynamics and planning of food interactions, these types of organisation are liable to cause ingestion of unrefined grazing forage at levels similar to those of grass silage, and to guarantee high levels of zoo technical performance whilst ensuring a fairly good control of scrub invasion dynamics.

Collective management projects

.... beef breeds

It is here question of research into the management of domestic animal populations. Thus, work carried out in the 1960s in connection with the Aubrac research project considered the local beef breed as indicative of a threatened culture. This attitude takes into consideration the geographical area and also local farm product handling and marketing (veal, Laguiole cheese); the breed was thus studied with reference to the work of ethnologists who were promoting this research (Leroi-Gourhan and his team) as a collective technical skill, defined by individual practices but also by collective functioning. Right from the start, the breed had social and geographical dimensions which were the basis for local development projects which have since proven to be efficient. Livestock researchers involved in the project were confronted with a dynamic and truly innovative livestock farming system, in a situation where the usual selection procedures, based on a large number of livestock farmers, could not be used : the Aubrac community nevertheless became skilled at modernising livestock farming systems whilst preserving its roots and identity (Vissac, XXXX). The animal breed constitutes a very important identity factor in local socio-technical networks which associate reproduction qualification processes, herd management techniques and original subsectors for products of character with high added value (Vallerand et al., 1994).

.... invention of a new farm sausage

New projects are created from a transformed product such as savoury dry sausage ("saucisson sec"). A new dynamic for creating a high-quality product, destined for sale during the summer tourist season, has been engaged by Corsican livestock farmers who have got together to revise the traditional manufacturing methods used for the sausage, usually made during the winter and marketed in spring, with this new perspective in mind: it is a question of changing from tacit know-how coming from the local technical context, to explicit know-how that is reproducible representing a guarantee for consumers, whilst retaining its craft status within sub-sectors that have few intermediaries. A new technical skill was thus created as a result of action-research, involving technological researchers with the livestock farmers and artisans concerned: saucisson "prêt au report" (i.e. that can be kept until the summer) which consists scientifically of modelling the pork maturing process (loss of water, fat oxygenation, etc.) elaborated using variations in the state of ordinary farm sausage. This has led to new manufacturing procedures (type of sealing, gut diameter, etc.) and new conservation techniques. The process involving the creation of a new technical product led to a new way of organising the actor-groups concerned, by making clear the rules of co-ordination vital to the success of their project.

... research aid for the negotiation regarding water quality

The nitrates research project mentioned above is a good example of research subject transference which was required in order to cope with a specific question which does not usually enter into the field of problems encountered by farmers : pollution of groundwater by fertilisation residue; it is a question here of the consequences of practices on aspects that do not directly come into the field of knowledge held by farmers, who firstly are not involved directly in water production (and therefore do not feel responsible for its quality) and also do not directly spread nitrates but organic and mineral fertilisers.

The invention of the notion of marginal productivity of nitrates by agricultural researchers and economists working together, in contact with their partners in the field, has thus enabled two worlds to meet up: that responsible for evaluating water quality (particularly nitrates content) and that involved in reasoning out marginal productivity of production factors (particularly costly inputs such as mineral fertilisers or undesirable intermediate products such as liquid manure). The negotiations were then carried out between these different categories of actor-groups using a new project, relevant for all and allowing simulation because it could be modelled.

Difficulties and research drift resulting from this collaboration between technical and social sciences, limiting the success of the systems approach

After the enthusiasm of the late 1970s which saw a huge expansion in the use of the systems approach in agricultural research, particularly in developing countries, a certain disappointment has prevailed since the end of the 1980s. Criticism has been levelled at the weakness of the theory and concepts of an approach considered to be too monolithic. In 1986, USAID and the World Bank began withdrawing financial support from a large number of projects, since progress in the field of this type of research appeared to be too slow and the results not very convincing by their standards. Edgar Morin, a fervent defender of systems approaches as a rule, has criticised the negative aspects of the reign of systemism[15], i.e. its general purpose and overly abstract side with which it distances itself from concrete issues (Morin, 1990)[16].

Generally speaking, this relative disenchantment, as to the capacities of systems research to respond to the needs of farming and farmers in developing countries, demonstrates that the real shortcomings of the approach have not always been dealt with. We feel that the failures can partly be put down to the lack of interconnection between systems research and analytical sector research, also to the relative incomprehension between researchers in the field (in the

[15] J.L. Le Moigne prefers to refer to systems science rather than to systemism (which has unfortunate ideological connotations) so as to underline the scientific challenge involved, allowing this discipline to exist as a "teachable discipline".

[16] Development must be "economically viable, ecologically sound, socially just and human, culturally appropriate (or correct), grounded in holistic science".

farms, in localities) and those working in research stations or laboratories, and often also to the excessive predominance of the social sciences. On top of all this, researchers in agrotechnical sciences sometimes drift into general agricultural research using superficial knowledge in the social sciences, which weakens their scientific integrity and field of enquiry. This research drift is probably particularly evident in developing countries where systems research was first introduced. It is interesting to point out the reasons why systems research has met with bad press, in spite of the considerable means at its disposal during the late 1970s and 1980s, particularly in Africa.

Systems research often produces correct diagnostic assessments clearly identifying the constraints which prevent farmers from adopting more suitable technology or which block the development of locality-specific product lines. But, due to a lack of interconnection with sector research, technical analyses are insufficient thus running contrary to the emergence of applicable solutions. Researchers working in research stations are insufficiently involved and cannot change their fields of enquiry quickly enough to incorporate the "discoveries" or priorities of systems research. This goes to explain in part the strained relationships that sometimes exist between researchers in stations ("who alone carry out scientific research"!) and systems researchers ("carrying out vital research work on the farms because the results of research undertaken in stations are not always of use to farmers"!). Furthermore, it must be acknowledged that the diagnostic assessments produced by systems research in the field are sometimes too general, or too superficial or too tied to socio-economic aspects, thus preventing concrete definition of priorities that could be apprehended and managed by sector research in stations and laboratories. Systems researchers are often rightly reproached for not making sufficient effort to limit their fields of expertise so that the themes studied become manageable.

It should also be pointed out that the technical themes produced by this systems research and these diagnostic assessments are often greatly removed or cut off from "mainstream" research undertaken in research stations: suboptimal research into the secondary characteristics of variety selection, research concerning small production units, etc. It is clearly frustrating and not to a researcher's advantage to engage in genetic research to produce varieties which cannot develop their full potential because local conditions do not enable this to be achieved. This contradiction is certainly of major importance in developing countries, particularly in international research centres, but is not specific to these countries. The livestock researcher, J.H. Teissier came to the same conclusions at the beginning of the 1980s as regards the lack of data available on mini-ranching techniques, which would have been useful in the Vosges mountains but which met with no interest in the laboratories.It should be recalled that responses to different development problems necessarily entail technical and organisational innovations. These responses are evidently elaborated collectively by the different actor-groups involved in agrarian systems under study. Interconnecting these two types of innovation is not easy, but we feel that this is of major interest for our societies and constitutes a challenge for systems research. This means that everything possible should be done to improve scientific collaboration between biotechnical sciences and social sciences, the latter not comprising economics alone.

While systems research is marking time in developing countries, nevertheless facilitating positive reflection about these inadequacies, it is encouraging to note that European research teams are carrying out interdisciplinary and systems research which is expanding greatly in developed countries. These European symposia are proof of this. These research teams have up until now maintained a low profile, and they do not have an organised structure, since the researchers involved in this type of research do not want to sever links with their original disciplines, which are however opening up to these interdisciplinary perspectives. This has led several of us to shelve for the present the creation of a European association for "systems research in agriculture and rural development", even though we have much to share outside disciplinary events like this meeting in Granada. But the fact remains that, in developed countries, research increasingly recognises the complexity of problems concerning development and protection of the environment that can be connected with agriculture, and increasingly uses systems modelling concepts, action-research and the interdisciplinary approach.

The situation is identical in North America (Brossier, 1994). In the case of the United States, it is interesting to note that at present these new systems research fields of study are most dynamic and are shooting up everywhere. This phenomenon has not been organised on a national scale; however trends are being set and certain questions are continually cropping up: complexity of research subjects and questions: erosion, pollution, sustainability, participatory approach, associating the actor-groups involved in the research. However, these research teams have had little contact with the Association for Farming Systems Research and Extension (AFSRE) which was set up several years ago (thanks to funding from USAID) and which brings together research teams working mostly in developing countries and using the Farming Systems approach (University of Florida, Michigan State University, University of Arkansas).

Training as an inherent component and condition of success of systems research, using the example of a INRA SAD research team[17]

The action-research approach cannot be envisaged without training. A research project involving a number of actor-groups incorporates training of these groups and their participation in the project can be subject to this training.The location of several INRA-SAD systems research teams' offices in the buildings housing agricultural schools, and the fact that several members of the teams are professor-researchers, doubtless explain the importance given to training in the research projects handled by these teams. This interconnection is an inherent aspect of systems research.

Using the experience of a INRA-SAD research team, three types of relationship can be observed (see Figure n° 3) between systems research and educational research:

– the concepts elaborated by research contribute to the progress of knowledge and thus to updating the training of farmers and advisors. Systems research into farm functioning has provided the means for going beyond a method of instruction based on technical knowledge to a method based on farmer action. Thus tools and methods such as analysis of farmer economic behaviour when making decisions, analysis of the farm in terms of

[17] The interconnection between research and education is important for all the SAD research teams. We take the example of the Versailles-Dijon-Mirecourt SAD research team. The ideas developed here owe much to Eric Marshall, long responsible for definition of the programmes in agricultural high schools and in professional training in the ENESAD Higher School of Agriculture, and also member of the INRA-SAD research team. He is currently the director of the ENFA Higher School of Agriculture in Toulouse. In a recent article, certain parts of which are taken here, E. Marshall identifies three types of relationship between systems research and educational research (Marshall E., 1986).

system (Family-Farm System concept), analysis of practices and techniques, enable teachers to consider the farm in a new light (see Figure n° 3a).

- educational experiments closely linking systems researchers and educational researchers, serve to elaborate a common field of interest. These experiments are indispensable for research because they enable concepts to be formulated and methods to be transferred ("produce teachable concepts" says Le Moigne). One experiment has been conducted with the participation of INRA-SAD, educational researchers and two agricultural high schools. This was not just a question of using the concepts formulated by research, but also involved the direct participation of SAD researchers in a teaching research project during which a joint scientific field was progressively elaborated. In addition, in order for research findings to be diffused to the greatest possible number of farmers and extensionists, it is indispensable to set up a training programme. This is the best way of testing generalisation of methods and their capacity to transfer into the farming sector (Figure n° 3b).

- the educational research field intersects with the SAD scientific field. Researchers have been led to work at length in close collaboration with farmers. The latter undertake to submit their practices to research observation since in return they acquire training which is the condition for farmer participation in this research work. The work undertaken by researchers represents a detour as regards farmer action, this detour giving the farmer a mirror image of his own reality and practices, enabling him to consider them more objectively and thus being trained. In addition, this involvement of researchers in professional training is not just a question of transfer of knowledge, but also the opportunity given to researchers to examine how far research has progressed, leading to new research areas of enquiry that emanate from the field (Figure n° 3c).

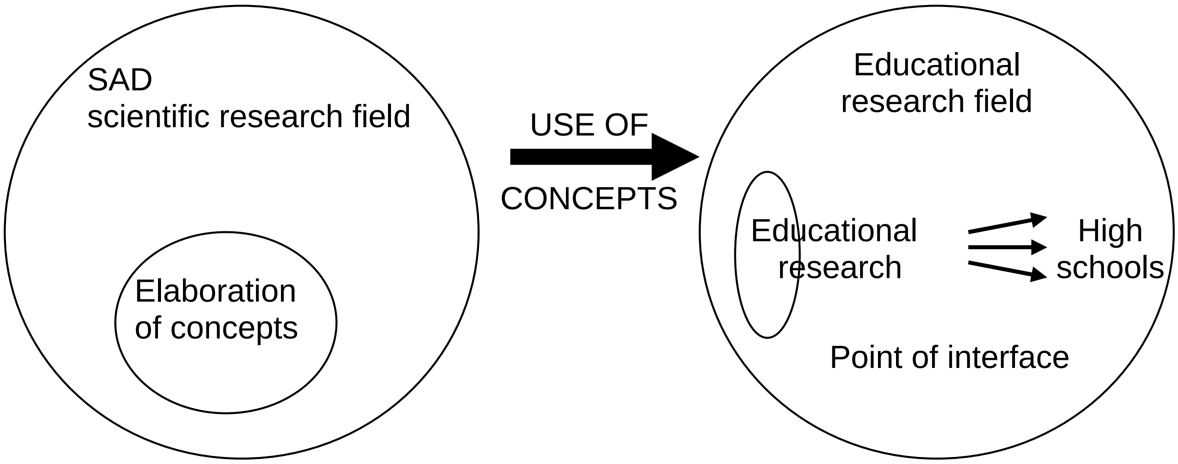
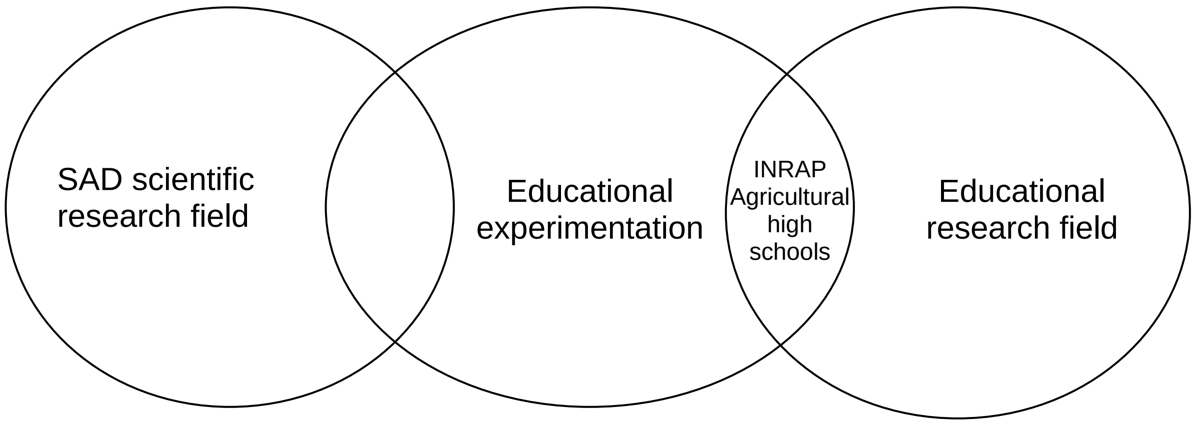
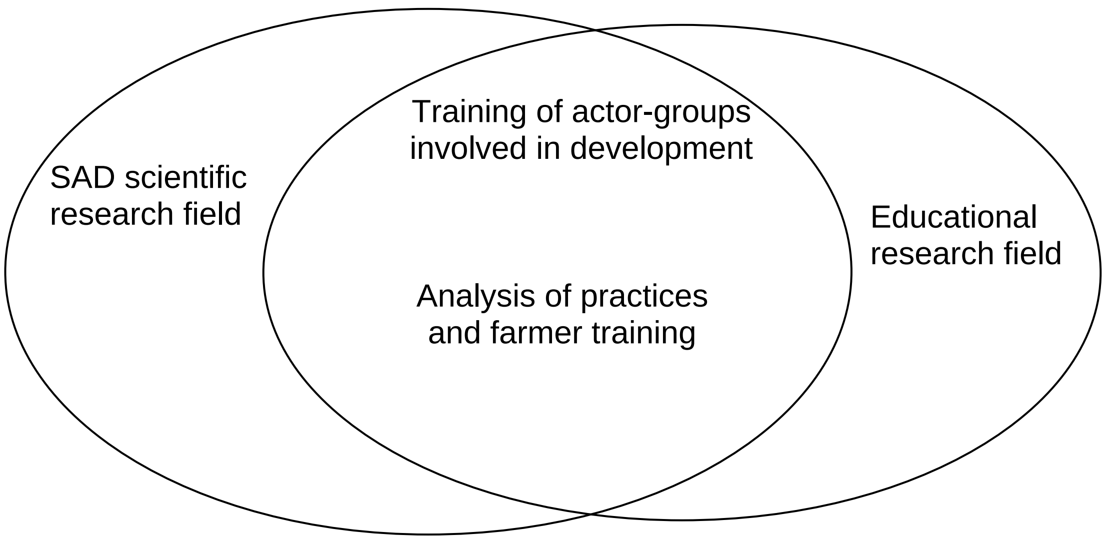


Figure 3a: first type of relationship



Elaboration of a common scientific field

Figure 3b: Second type of relationship



The educational research field enters into the SAD research field

Figure 3c: Third type of relationship

Conclusion

Thus is outlined briefly a field of research closely associating science and action. Institutionalising this field of research within INRA has given greater visibility to the sciences of complexity, since the INRA SAD department is founded on the close interdisciplinarity of natural sciences, technical sciences and social sciences, and their interface with training. Its scientific field has been built on the study of technical systems, which incorporate biotechnical and social dimensions. INRA SAD aims to apprehend all the facets of the multiple consequences of decisions taken with respect to agrarian systems. INRA SAD researchers feel that they have an essential role to play in "innovation networks" which is where the different viewpoints of actor-groups converge, where mutual learning takes place, and where know-how is elaborated and combined.

One of the criticisms that can be levelled at this type of approach is that of the local nature of the issues examined which thus have little generative value. In other words, what is the scientific value of constructivist systems research, inductive methods and case-studies? There is nothing new about the general question relative to the scientific status of these methods. This has long preoccupied researchers studying complex systems such as ecologists involved in developing the comparative analysis method, or social science researchers among which J. Clyde Mitchell who, as a theoretician of innovation networks, has developed the notion of logical inference as opposed to statistical or enumerative inference. He is of the opinion that "the degree to which generalisation can be made using case-studies, depends on how apt the underlying theory and all available knowledge are to the case-study rather than on the specific example itself" (Clyde Mitchell, 1983).

Along with Passeron (1961), we have our reservations due to the very specificity of empirical research which aims to represent the world using observation and monitoring of specific situations (non-reproducible situations, difficulties met in making strict definitions of the initial conditions, etc.) rather than using experimentation as is the case with traditional experimental sciences. Comprehension of meaning, plus theoretical and conceptual interpretation induced from this empirical research are doubtless neither refutable nor "falsifiable" in Popper's sense of the word. The important thing is the way in which, given a specific case, contingent problems and scientific knowledge interconnect, and how an analysis and action process actually functions (Berry, 1986). And yet these methods produce "teachable concepts", because in the course of our work we produce methods for elaborating descriptive models, functioning models or decision-making models according to whether we are seeking to explain the structure and functioning of an organisation, or to identify the similitudes and correlations between phenomena in order to predict probable changes or to invent decision-making tools. Thus in situations such as mineral water protection, we have designed methods and models which are in fact processes[18] facilitating the collective invention of solutions. These methods can be generalised to other situations involving the management of natural resources. In a nutshell, it is the aptitude of systems research to give coherence to the observed phenomena and to make them intelligible, and also to render action relevant, that validates the modelling and methods that have been elaborated and gives them generative value.

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[18] In the report from the methodology workshop at the Montpellier symposium in 1994, Peter Matlon summed up in the following way: " It was agreed that the main product of models is the learning that takes place during conceptualisation and validation, not the analytical results themselves ". (Matlon 1996).

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