How do livestock and crop sciences represent evolutions of farming systems? A review

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Abstract: *Farming systems have to evolve in order to face increasing uncertainty in their environment. In this review we analyse evolutions of farming systems over the long term as a double co-evolution: co-evolution of the farming system and its environment, and co-evolution of the farmer and his biotechnical system (farmer activity). We review literature from the livestock and crop sciences, and we deepen our analyse with some literature from management sciences, ergonomics, professional didactics that were cited or significantly related to long term approaches to crop or livestock farming systems. Learning is usually cited as an interesting evolution process. In agronomy, farmer activity has been modelled through the model of action, and the model of behaviour for action: these models respectively represent farmers' actions as planed on the one hand and as partly planed and partly emerging while they are happening on the other hand. Those representations are built according to a stable professional norm of the evolving farming systems that doesn't allow any important shift in the farming system over the long term. Representing evolutions of farming systems that last over the long term requires integrating learning with farmer activity.*

Keywords: farming system, long term evolution, learning

Introduction: facing uncertainties of the environment to last over the long term

In recent decades, farming systems have had to cope with increasing uncertainty. The environment of farming systems is evolving at a faster rate and has involved larger geographical and time scales since the industrialisation of agriculture (Deléage, 2004). Agricultural systems in Europe are less and less protected against these rapid evolutions: since 1992, successive reforms of the common agricultural policy have diminished the protection of the agricultural product market, progressively opening the door to free exchanges and generating fluctuations of market prices and economic uncertainty (Dedieu et al., 2008). Ecological risk concerning farming systems increases: climate change, for instance, enhances an increasing frequency of climatic accidents. This raises a crucial question about long term evolutions of farming systems (Darnhofer et al., 2010) and the way to cope with long term preservation and short term adaptations.

Based on the general definition of the system (Le Moigne, 1990), farming system has been defined as the combination of the information and decision system of the farmer and the biotechnical system, linked by agricultural practices and information flows (Osty and Landais, 1993). This definition has been used for livestock farming systems (Landais, 1987; Dedieu et al., 2008) and cropping systems (Sebillotte, 1990). So the farmer is represented as the pilot of the biotechnical system, for example the herd and fields: the pilot develops a farming project, organizes practices that lead to the desired production and to a renewal of the resources, taking into account information coming from the biotechnical system, such as the crop yield, and also information from the general environment. This general environment is composed of climate, prices of agricultural products and inputs, information from advisors and other factors. Farmer decisions are also built referring to locally constructed professional and social norms.

We propose to focus our interest on the representation of evolutions of farming systems over the long term with a literature review in order to understand paths and processes mobilised by lasting farming systems. Farming systems have been studied by many agronomists, but also by social scientists; in this text, we review literature from the systemic livestock and crop farming sciences' point of view. These scientific communities are part of agronomy and animal production disciplines devoted to farmer – techniques and biology interactions (Gibon et al*.,* 1999). Based on the analyses of this literature, we then deepen our analysis with some literature from management sciences, ergonomics, professional didactics and sociology that were cited or significantly related to long term approaches to crop or livestock farming systems. This review does not claim to give an exhaustive point of view of the long term approaches built on farming systems in biotechnical and social sciences but aims at summarising mainstream approaches developed in farming system agronomic communities during the last 30 years. In the first section, we will review and discuss approaches to farming system operations with a long term perspective. In the second section we will review action models available to represent farmer actions in their farming systems, focusing on the evolution processes involved in the interaction between farmer and the biotechnical system over time. In the third section, we will expose the research questions involved in the introduction of evolution processes in the representation of farming systems.

Farming system operation with a long term perspective

Diverse studies dealing with farming systems over the long term have been developed in crop and livestock sciences. They are based on several methodologies, such as implemented farming system modelling, farmer interviews focused on family – farm trajectories; farm monitoring or long term experiment. These studies are carried out over a pluriannual time step: they include several agricultural years. They differ by the consideration of structural and biotechnical traits and operation of farming systems over the long term, but also by the consideration of the interactions between farming systems and their environment.

Evolutions of farming systems over the long term: traits and operation of systems and experience of farmers

Agronomical studies dealing with farming systems over the long term are constructed according to diverse representations of farming system traits, and the opportunity of the farmer to change over time. These representations appeared progressively in recent decades, even if their diversity still exists in current studies.

Most of the agronomical studies have been carried out considering the structural and biotechnical traits and farming system operation as stable over a continuous time step. The implicit representation of production systems over the long term then consisted of a succession of stable system states following a succession of periods. These studies are mainly focused on biotechnical performances of fixed farming systems. The farmer is represented through his agricultural practices: opportunity to change his rules is not taken into consideration.

In these studies biological properties involved in the biotechnical systems are usually represented as static, the researcher assuming a reduction in order to simplify the representations. Capillon (1993) formalised evolutions of farming systems over the long term as a succession of stable states of the system without transition. These stable states of system (Aubry et al., 1989; Capillon and Tagaux, 1984) are defined according to the socio-economic objectives of farmers, their decision rules and the structures of the farms. These stable system states are implicitly assumed to be a repetition of a stable agricultural year. This representation of farming systems over the long term has been applied in long term experiments. Humphreys et al. (2008) compared 4 grazing dairy systems in a long term experiment in Ireland: these systems differed by the stocking rates increasing from 1,75 to 2,5 cows.ha^{-1} and associated N input increasing from 205 to 400 kg.ha^{-1}. They compared their biotechnical performances (milk productivity and nitrogen fluxes) over a 2 years period without explaining the past situations of the 4 systems and the steps to set them up: time was divided into periods without transition even if progressive changes may happen, such as the progressive evolution of the amount of legumes in pastures...

As farming system modelling emerged, researchers started to represent biological processes involved in biotechnical systems as dynamic even for pluriannual processes. They took into consideration interactions between biological cycles and feedback relations between biological processes. Landais (1987) defined evolutions of livestock farming systems as cyclic over the long term. He referred to the "round time" and "long time" in a conceptual model. "Round time" represents repetitive actions of days and seasons, which is a common approach for herd management like feeding and reproduction practices, and "long time" represents longer periods, like lifetime performance of animals. This representation has been developed in several mathematical models to study performances and regulating properties of farming systems. In these [farmer rules – biological processes] models, the farmer's opportunity to change his rules is not taken into consideration but adjustment rules, to face identified fluctuations of the biotechnical system, might be integrated and assessed over the long term (Coléno, 1997; Cournut and Dedieu, 2004). For example, herd demography relies on pluriannual biological processes: it depends on reproduction performances of the females and their survival rate in the herd. The dynamic model of herd composition of Cournut and Dedieu (2004) is based on a representation of each reproductive female: It considers the diversity of biological responses of each animal to management rules and implements adjusted rules to individuals in order to regulate herd demography.

These approaches based on stable biotechnical traits and operations of farming systems over a continuous period are centred on biotechnical performances of farming systems: The introduction of evolving biological processes and adjustment of management rules makes it possible to assess regulating properties of farming systems when a lack of performance parameters is implemented. For example, Tichit et al. (2008) showed that keeping a diversity of lifetime performance in reproductive females of flocks and herds ensure regulation of herd production over the long term.

Few recent studies in agronomy have been developed considering the operation of farming systems as evolving over a non continuous time scale. Long term is represented as a succession of stable and transition periods. These studies are mainly focused on a global approach to farming systems including the farmer and his biotechnical system. They are usually based on analysis of farm trajectories representing the evolution of structural traits and operation of the farming system over the long term. The farmer is explicitly represented in theses studies and the changes in management rules are represented over the long term. Biotechnical traits and operations of the systems evolve but are not always precisely represented, as are other elements such as labour, other activities of the household...

Moulin (2007), studied sheep farmer technical trajectories in La Crau (France), by considering short term events of the farming system that made the trajectory evolve over the long term (change of breed, change of ewe replacement practices …): these events were characterised according to what must be kept in the system (norms, values, specific practices, commercial strategy…). Time is represented as a succession of relatively continuous periods and transition periods. The analysis of the farming system is particularly focused on transition periods (traits, operation and practices): for example a few shepherds choose to start industrial cross breeding for commercial reasons. Moulin analyses the long term consequences in terms of practices (how to carry on self-replacement of ewes?) and characterises what must be kept (for example: commercial strategy…) over time. Long term consequences of practices during stable periods are not analysed.

Some agronomists have deepened the "paths to last", notably in livestock farms with a family – farm – combination of activities of the household analysis (Levrouw et al*.,* 2007; Begon et al*.,* 2009; Dedieu, 2009). Their common framework is the adaptive cycle of Holling (2001) that represents the temporal inscription of farming system trajectories. This approach is also mobilised by other disciplines like socio-economy (Milestad and Darnhofer, 2003). According to Holling (2001), human systems, or socio-ecological systems follow adaptive cycles and are interdependent. Socio-ecological systems follow different phases during their lives represented as a succession of learning periods and reorganisation periods, the latter in order to face shocks or big changes in the environment. The learning period is seen as a slow period of accumulation of capital (skills, nutrients…) for the system. The reorganization phase is marked by innovation and followed by a new period of learning and accumulation of capital. Past evolutions of traits and operations of farming systems might be used in a long term experiment: for example, the long term experiment of ASTER-Mirecourt (Coquil et al., 2009) aims at establishing rules to manage self-sufficient mixed crop dairy systems over the long term. Rules of management and characteristics of the system evolve by the incorporation of past experiences: trial and error, ways to face climatic accidents like excessive rainfall one year...

More recently, some research was focused on the transition periods of evolving systems in order to understand the unforeseeability of the moment when transitions happen and their issue, and the irreversibility of their consequences. Transition periods are also analysed looking at the link between short term events and their long term. Lamine and Bellon (2008) focused their studies on a special transition period of farming systems' technical and social trajectories: the conversion to organic farming. This period is fixed at 3 years according to European legislation. According to Lamine and Bellon (2008) the creation of new agronomical balances and techniques during the conversion might happen on different time steps through different paths. Focusing on the conversion of market gardeners and arboriculturists to organic farming, Lamine and Perrot (2007) demonstrated that the evolution of disease management was central in the technical conversion and may happen through different paths and at different moments of the farming system trajectory before or during the administrative conversion. Kummer et al. (2008) focused their study on experiments of organic farmers in Austria to analyse transitions: they analyse what stimulates these experiments and what kind of long term effect they had in farming systems. Agronomists studying the technical trajectories of farming systems over the long term showed that the transition period, i.e. levers for adaptation to shocks, depended on the long term strategy of the farming system (Levrouw et al., 2007; Begon et al., 2009; Dedieu, 2009). For example, the reaction of French dairy producers (Segala, centre of France) to the severe drought of 2003, depended on their long term strategy (Begon et al., 2009).

In the end, most of the biotechnical approaches to farming systems are constructed according to a static vision of the farmer and his decisional system over the long term in a stable or predictable environment. Uncertainty is not taken into consideration, and evolution of the farmer, influenced by his neighbourhood, by commercial information… building his professional norms within his local network, is not considered. Since the late nineties, a few approaches have been built according to an evolving vision of farming systems over the long term: this vision is essentially focused on the farmer. Biotechnical traits and operation of farming systems are mainly analysed during transition periods referring to stable traits of the system (Lemery et al*.,* 2005; Moulin, 2007; Tichit et al., 2008). Time has to be considered as a succession of stable and transition periods. Holling (2001) proposed a conceptual model representing an evolving farming system over the long term following an adaptive cycle. But there remains a difficulty in representing co-evolution of biotechnical, structural traits and operation of farming systems including farmer practices. If long term strategies appear to influence short term adaptation levers, there is no literature: what are the consequences of everyday small changes on the long term strategy of farmers? Holling (2001) proposed 2 processes for evolutions of farming systems: learning and reorganization.

Interactions between farming systems and the environment over the long term: adaptive capacities

In agronomy, concepts have been defined in order to qualify and explore evolutions and adaptation capacities of farming systems in a disturbed environment, including hazards and severe shocks. These concepts have been focused on the system's properties (Papy, 1994; Dedieu et al*.,* 2008) and on system processes (Holling, 2001) to face unknown evolutions of the environment.

In the literature, two main concepts define farming systems' properties to last over the long term in an uncertain but identified environment: room for manoeuvre and flexibility. These concepts imported from management sciences have been developed in crop science and livestock science since the nineties.

Room for manoeuvre defines the panel of risks that can be faced by a farming system by considering the adjusted rules that can be built without changing structure traits and operation of the farm.

Room for manoeuvre was first applied to cropping systems (Papy, 1994) to define the panel of risks from the environment that can be taken in charge by the traits and operation of cropping system and the possibility for the system to cope. For Martin (2009), room for manoeuvre is defined in forage systems by identifying *(i)* possible biotechnical adjustments of the system (span of use – production and digestibility of the different covers) and (ii) several functions to each production entity (can grassland be pastured or harvested?). Attonaty et al. (1987) applied the room for manœuvre notion to work organization in cropping systems: the concept is used to assess allocation of material and labour in order to assume high periods of intense work in the cultural calendar for various pattern of climate. Dedieu (1993) define the "calculated free time" as the room for manoeuvre left by the farm work organization formula (efficiency of work, delegation).

Flexibility is defined as the system property that allows them to absorb changes in their environment (Guégen, 1997; Reix, 1997). Flexibility is built by farmer practices and biological robustness. It also integrates objectives and the risk perceptions of farmers. Flexibility associates paradoxical properties such as stability and change (Alcaras and Lacroux, 1999), and it is able to create links between short and long term (Lev and Campbell, 1987). Several studies have been carried out in order to qualify the diverse sources of flexibility that can be mobilised by farming systems facing an uncertain socio-economic context (Petit, 1981; Dedieu et al., 2008): technical flexibility, commercial flexibility… Flexibility sources of a system are designed according to targeted fluctuations of its environment (De Leeuw and Volberda, 1996). A panel of risks can be avoided using a panel of flexibility sources (Dedieu et al., 2008). De Leeuw and Volberda (1996) distinguished two types of relations between the system and its environment: the system can be represented as the controlling organ (autonomous system) acting to avoid fluctuations of its environment (target system), or it can be represented as the targeted system (controlled system) being prejudiced by its environment (controlling organ). These perceptions of being in control or being prejudiced were formalised for livestock farming systems (Lemery et al., 2008), facing uncertainties of production and processing networks.

Room for manoeuvre and flexibility define the adaptive capacities of a farming system in a defined future environment. Room for manoeuvre is an inherent property of the system: operation of the system does not evolve to enhance room for manoeuvre. Flexibility is constructed by farmers: structural, biotechnical traits and operation of the system might evolve to face uncertainty.

The process approach to farming systems evolving in a perturbed environment can be summarized with the resilience literature. Resilience is a concept that has been developed in physics and ecology: it initially describes the property by which physical materials and ecosystems come back to their original state after being shocked (Holling, 1973). This concept has progressively been used by ecologists to describe and formalise adaptive processes of social systems (Gunderson et al., 1995). Nowadays, flexibility and resilience are quite close. However, resilience is defined through a more dynamic process, and takes into account co evolution of the system and its environment and the occurrence of shocks that require a kind of re–design of systems (Holling, 2001). According to Holling, human systems, or socio-ecological systems follow adaptive cycles and are interdependent. Socio-ecological systems follow different phases during their lives according to the system potential, its connectedness and its resilience. During the learning phases, the potential of the systems, seen as the range of future options of the system available for change, and the connectedness of the system, defined as the internal controllability of the system, increase. But during the learning phase, adaptive capacity, or the resilience of the system, decreases. This learning period is seen as a slow period of accumulation of capital (skills, nutrients…) for the system. When the connectedness and the potential are high with small resilience, the system is vulnerable facing a disturbance: if it happens, potential is released and organisation has to be rebuilt. The reorganization phase is marked by innovation to start again a period of learning and accumulation of capital.

Adaptive capacities of farming systems might be approached by several concepts (Dedieu, 2009). Describing the evolutions of farming systems in an uncertain environment can be considered by: *(i)* assessing the possible adjustments that can be built for a system (room for manoeuvre) and developing regulation properties of biotechnical systems (Tichit et al., 2008), *(ii)* building alternative operation of farming systems or alternative systems to face probable risk that might happen in the future (flexibility), or *(iii)* focusing on evolution processes mobilised by farming systems to last in order to build a generic approach, with less consideration for the system properties and the possible future environment. Individual learning of farmers to face uncertainty of the environment is globally recognised as one of the evolution processes in the literature (Hale and Glendon, 1987; Jiggins and Röling, 2000; Milestad and Darnhofer, 2003; Berkes and Turner, 2006; Chia and Marchenay, 2008; Kummer et al., 2008).

Farming system evolutions over the long term: where are the farmer's experience and learning?

According to the literature, long term evolutions of farming systems involve two levels of interactions: co-evolution between the farming system and the environment and co-evolution between the farmer and his biotechnical system through the evolution of farmer activities (Leplat, 1997).

As reviewed, evolving interactions between the farmer and his biotechnical system have mainly been studied *(i)* using a stable representation of the system over the long term: studies are focused on biotechnical performances of farming systems considering farmer experience as fixed, or *(ii)* using an evolving representation of the system: studies are focused on the reasons for changes in the farming system, and evolutions of the biotechnical system are analysed just during the transition period.

Holling (2001) defined co-evolution of the system and its environment by the panarchy: socio-ecological systems are interdependent and co-evolve. Panarchy can be defined as the organization of the systems according to space and time: quick cycles that happen at a small scale can cause critical change (revolt) to cascade up to a vulnerable stage in larger and slower cycles; accumulated potential of slow and large cycles can be used for renewal of smaller and quicker cycles (remember).

Many authors consider learning as a process of farming systems evolutions in their environment over the long term (Hale and Glendon, 1987; Jiggins and Röling, 2000; Holling, 2001; Milestad and Darnhofer, 2003; Berkes and Turner, 2006; Chia and Marchenay, 2008; Kummer et al., 2008). Learning has not yet been well developed in long term studies of farming systems, but organizational learning was used to analyse long term strategies of lasting enterprises by Mignon (2009). Founding farmer learning on their experience might be an interesting research subject to consider the long-term evolutions of farming systems in the environment. But this makes it necessary to grasp and understand how farmer action evolves.

Farmer actions

In recent decades, farmer action has been represented in two main models by French agronomists: namely "action model (Sebillotte and Soler, 1990) and *farmer behaviour for action* (Girard and Hubert, 1999)". These models consider farmer action on the agricultural year time step. In these models long term evolution of the activity is implicitly built through the definition of the strategy (Mintzberg, 1987). Mintzberg (1987) defines strategies as abstractions which only exist in the minds of interested parties: strategies can be seen as intention (or plan) to regulate behaviour before it takes place or inferred pattern to describe behaviours that have already occurred.

Action model

The farmer action model (Sebillotte and Soler, 1990) is based on the expression of a strategy in operational actions. In this representation of farmer actions and decisions, intention and planning are central. Action model structures farmer perceptions of their situation and fixes their decisions and actions to fulfil their objectives. Alternative strategies, or modifications of the action plan in order to avoid a number of events, are anticipated: farmers act according to a procedure and adjust their decision according to the gap between observed and anticipated situation, by applying predefined procedures or alternative solutions. This representation of farmer decisions and actions has been well used and developed in agronomy.

Based on the farmer action model, Sebillotte developed two fundamental concepts of agronomy to model crop farmer decisions: crop management sequence (1978) and cropping system (1990). The crop management sequence is defined as the logical and ordinate combination of cultivation techniques in order to control natural elements for a targeted production. The cropping system is defined as the overall techniques applied to fields cultivated in the same way, including crop rotations and crop management sequence for each crop. In the cropping system, decisions are mainly represented at the field scale and at the agricultural year time step. Aubry (2007) developed these concepts to formalise technical decisions of crop farmers at the farming system scale. She focused on *(i)* the allocation of productive resources to the crops at the farming system level and *(ii)* technical management of the crops on the agricultural year time steps. Decisions of crop farmers have been modelled at the scale of the area under each crop. Farmers take technical decisions for the totality of the area under each crop according to observations of one or several fields for each crop, called “parcelle-guide”. Maxime et al. (1995) modelled farmer decisions to allocate land resources to the different crops at the farming system level. She defined this as an iterative approach built by farmers. They take into account 4 technical indicators: potentially cultivated area for each crop, delay for the crop return on the field, potential preceding crop and needed size of the crop area.

The farmer action model has been used to model farmer actions for other agronomic entities like forage systems (Coléno 1997), slurry and manure management (Aubry et al*.,* 2006). In crop and livestock sciences, most mathematical models of farming systems implemented consider the farmer accordingly to the model of action (Cournut and Dedieu, 2004, Martel et al., 2008; Jouven and Baumont, 2008). These models might represent a complex environment of farming systems (Martin-Clouaire and Rellier; 2005; Martin, 2009).

Model of farmer behaviour for action:

Girard (1995) proposed the representation of farmer actions as a progressive construction in time and space. Farmer actions make the continuum between plan and adaptation. So as Mintzberg and Waters (1985) said: planned strategy has to be completed by an emerging strategy to face unanticipated events. The accomplished pattern is thus a combination of both the emerging and the planned strategy. Girard and Hubert (1999) made a fine analysis of the practices of suckler sheep farmers over an agricultural year: the agricultural year is progressively defined by farmers, prioritising actions according to their relative importance over the short and long term, to realize their production project. In the end, Girard and Hubert represented the farmer according to his capacity to combine, prioritise and make trade-off between activities to fulfil his objectives. Strategy is there as a realized pattern in the model of farmer behaviour for action (Girard and Hubert, 1999). Intention and planning are just a part of the pattern: emerging choices to face uncertainty complete this pattern. In the model of farmer behaviour for action (Girard and Hubert, 1999), evolution of practices over time is recognized but not modelled because the representation is built on the agricultural year time step. Representation of farming system evolutions has to concentrate on the emerging actions that make the plan change on different time steps.

Evolving the frame of action over the long term:

Can “the model of action” and the “model of farmer behaviour for action” take account of evolving processes of the interactions between the farmer and the biotechnical systems? Those two existing models of farmer activity rely on different theories of action.

The “Farmer action model” (Sebillotte and Soler, 1990) refers to the theory of rational action (Simon, 1978). This theory models action as a rational strategy (or a plan), which has been formalised in order to fulfil determined objectives or ends, that action will accomplish. But as highlighted by Joas (1999), the theory presupposes that the player *(i)* is able to act according to the target, *(ii)* has full physical capacities and manages them to be able to act, and *(iii)* has a high autonomy in decision-making regarding his environment. These presuppositions are strong and usually not respected in farming systems because of *(i)* their internal complexity and interdependence with their environment, making planning impossible over the long term and *(ii)* the link between farming systems and family, increasing the complexity in fixing targets. For example, in self-sufficient mixed crop dairy systems, crops and livestock are usually interdependent but do not happen on the same time steps (crop: agricultural year and dairy herd: pluriannual): fluctuations of crop performances might make planning of herd diet and demography quite difficult over the long term (Coquil et al., 2009).

On the other hand, the model of "farmer behaviour for action" (Girard and Hubert, 1999) refers to "situated action and cognition" approaches (Suchman, 1987, Hutchins, 1995), which support empirical and theoretical arguments that the full anticipation of action (a plan) is impossible. In action, people encounter unforeseen situations and oppositions linked to singularity of a setting and contingencies (for example systematic deregulation of tools, instability of the matter to be transformed, etc.). Then, whatever the effort put into planning, performance of the action cannot be the mere execution of a plan: one must adjust to the circumstances and address situation contingencies, for instance, by acting at the right time and by seizing favourable opportunities. Accordingly, the organization of action is understood as a system emerging in situ from the evolution of interactions between an actor and a setting. So, in *situated* approaches, a great deal of behaviour organization is removed from the player, and attributed to the property of a situation or to the social norms of professional or social groups (de Fornel and Quéré, 1999).

Finally, on the one hand (the theory of rational action), farmers have a full autonomy; but on the other hand (the theories of situated action and cognition) farmers are dominated either by the situations or the norms.

We believe that none of these approaches can account for the reorganization of the action appearing in the long term. More precisely, we assume that the definition of a plan by the player (the theory of rational action) and the adjustment to the circumstances and contingencies (the theory of situated action) are situated in a "frame of action", which evolves over the long term process through learning and development of action. Mignon (2009) also highlights that in several theoretical models of learning, distinction of learning levels is built according to the change of frame: incremental improvement of existing procedures (in the same frame), or search for new solutions, by experimenting innovations and by taking risks (change of frame). Argyris and Schön (1978) distinguish two learning processes according to the situation and the size of the shift to make from the current situation to the future one: they talk about learning in "simple" and "double loop". In the first case, learning appears inside a frame, but in the second case (double loop), people change their frame. Model of action and model of behaviour for action are situated inside such frames, but they cannot represent a change of frame that might happen over the long term. For example, an intensive farmer who converts his farm to organic agriculture does not built and adjust his pattern in the same frame before and after the conversion. To represent long term evolutions of farming systems, we have to analyse how farmers make their farming system evolve in a frame, and how they make their farming system change frame. Béguin (2003) and Béguin and Cerf (2004) proposed defining the frame as a "professional world". A professional world (Béguin, 2004) is defined as a point of view of a reality: it is an oriented description of the reality to be efficient for players. "Professional world" postulates an oriented creativity that integrates the production of his environment by the player.

Discussion and conclusion

Long term evolutions of farming systems involve two levels of interactions: co-evolution between the farming system (Osty and Landais, 1993) and the environment and a co-evolution between the farmer and his biotechnical system. Co-evolutions of farmer and his biotechnical system have been studied in recent decades, in crop and livestock sciences. Studies either focused on the biotechnical traits and operations of farming systems, considering the farmer and his decisional system as static over the long term or focused on the farmer, with a limited analysis of the biotechnical traits and operations of the system. These studies rely on different representations of time: studies focused on biotechnical properties of farming systems consider time as a succession of stable periods and studies focused on the farmer consider time as a succession of stable and transition periods. These studies also rely on different considerations of biotechnical processes involved in farming system dynamics, sometimes representing them as static, in order to simplify the representations, sometimes representing them as cyclic, and sometimes representing them as evolving over the long term. Finally, long term studies in crop and livestock sciences have developed different considerations of adaptive capacities of the farming systems, from the regulating properties of biotechnical systems to the socio-ecological resilience of the farming system: adaptive capacities of systems have mainly been developed according to an identified or probabilised future environment.

Holling (2001) defined co-evolution of the system and its environment by the panarchy: socio-ecological systems are interdependent and co-evolve. Through this representation, Holling invites us to go further than the definition of ways to face probabilised future environments, by focusing on evolution processes of farming systems. Learning is recognised as a process mobilised for farming system evolutions over the long term, but it has not yet been developed in long term studies of farming systems.

In crop and livestock sciences, the processes of interactions between the farmer and his biotechnical system are tacitly or explicitly represented according to the model of action or the model of behaviour for action on different time steps. These two existing models rely on different theories of action limiting the possibility of integrating adjustments to circumstances and contingencies in farmer actions. They represent farmers as players in a particular frame: change of frame, which might happen in long term evolutions through learning, cannot be represented using these representations.

Learning and funding of farmer experience might be an interesting research object to consider long term evolutions of farming systems in their uncertain environment. Analysing farmer learning considering evolutions of their biotechnical systems and their environment might be a way to understand co-evolutions of farmers and their biotechnical systems and of farming systems and their environment over the long term. Learning might happen in different kinds of situations and is a permanent process. For example, learning by acting is presented as permanent in professional didactical literature (Leplat, 1997): trial and error, experiential learning… Sense-making of actions is an on-going process (Weick, 1993). Learning is affected by the action's context (Astier, 1999): it depends on the working environment, the opportunity, the player and the action (Bardin, 1998). Introduction of the learning process in the representation of farmer activity might question several acquisitions of the farming system model: can a farmer be represented just as a decider? Do farmer practices represent all farmer activities?

Representing farming system evolutions over the long term makes it necessary to represent the learning process of farmers. We propose to study farmer learning by analysing the technical and organisational trajectories of self-sufficient mixed-crop dairy systems. We propose to analyse these trajectories by referring to the farmers' professional world and by qualifying learning according to this professional world.

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