Prototyping sustainable dairy systems by evaluating their flexibility and plasticity in a system experimentation

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Abstract: *Resilient farming systems are systems which have survived from period to period. When we consider elements relative to the farmer, that is to say choices, decisions and learning processes, we use, like some other authors, the concept of flexibility. Socio-technical systems are supposed to be flexible when they have the capacity to respond or to conform to new or changing situations. The research team of Mirecourt (INRA) prototypes farming systems focusing on agro-environmental sustainability. Prototyping is organised around a pluriannual experimentation at the system scale. Such experiment might be well adapted to prototype resilient farming systems and decision rules by studying the flexibility of the whole system together with the plasticity of the biological elements within the system (crops, animals…). Thus prototyping could be a good help to create applied knowledge on innovative systems.*

Keywords *: prototyping, farming systems, sustainability, resilience, flexibility.*

Introduction: the increasing uncertainty of the farming context

Frequent changes in the CAP, increase of environmental and welfare regulations, sanitary crisis, global change of climate… are many examples of the changing context in which farming systems have to survive. The level of uncertainty becomes higher and higher concerning the future. Thus, resilience becomes a main property of sustainable farming systems. Flexibility is defined as a way to keep a consistency when the system is controlled by a human (maintain the objectives and the organisation), in a changing environment (Chia and Marchesnay, 2006). *Ex post* studies allow to evaluate sources and amounts of flexibility of the surviving farming systems by analysing their temporal trajectories (Lémery *et al.*, 2006). The challenge in prototyping sustainable farming systems is to anticipate flexibility sources for each prototype in order to create *ex ante* resilient farming systems for the future. In this paper, we propose a methodological framework and present the expected results illustrated by examples, in order to prototype sustainable dairy cow farming systems.

Material and methods: flexibility sources in the prototypes

Prototyping methodology consists of designing, evaluating and modelling innovative systems (Coquil et *al.*, 2007). In the experimental farm of the INRA of Mirecourt, two dairy cow farming systems are prototyped, focusing on agro-environmental sustainability. The main objectives of both prototypes are to: *(i)* preserve resources like water and air quality and fossil energy, *(ii)* be productive *(iii)* use environmental compounds, like animal and vegetal biodiversity and soil fertility, for agricultural systems purposes. The two connected dairy systems tested since 2004 are low-input systems in accordance with the specifications of the organic farming rules: a grazing system (GS) and a mixed crop dairy system (MCDS).

Both systems are managed following multi-objectives decision rules (Sebillotte and Soler, 1990) which are composed of *(i)* piloting indicators, which refers to the observations used by the manager to decide and act on the system, *(ii)* decision tree, representing the multi-factorial property of a decision before acting and (iii) evaluating indicators, in order to evaluate the accuracy of the decision to meet the objectives.

The decision rules are evaluated regarding both the decisional and the operating sub systems, as defined by Le Moigne (1984). Regarding the decisional aspects, we evaluate the practical feasibility of the decision rules at the system scale. This evaluation is done by analysing the discussions within different groups of people (within the INRA Unit) in charge to apply a decision rule and/or to manage the system. Making the hypothesis that there is a cause/effect relationship between the configuration of the system and the decision rules that are applied in the system, we analyse the evolutions of the system together with the decision rules applied during the experiment in order to identify the different sources of flexibility of the systems.

Regarding the operating aspects, we evaluate biotechnical feasibility of the decision rules. This evaluation is done by an agro-ecological evaluation: it relies on basic measures on the dairy herd and in the fields. We want to evaluate the plasticity of the biological elements of the systems at a pluriannual scale. Plasticity is defined as the adaptation capacity of the biotechnical system to a flexible system control (Dedieu *et al.*, 2001).

Expected results: Resilient farming systems

During the experiment, farming system and decision rules, designed *ex ante*, are considered as “target system” and the global changing environment of the system is considered as the “controlling organ” as proposed by De Leeuw and Volberda (1996). To achieve its objectives the “target system” has to adapt progressively to survive to the unpredictable events of the “controlling organ”. By the end of the experiment, “the target system” will have been tested facing a large range of events coming from the environment. The farming system and decision rules will be supposed to be non sensitive to variations within the environment: in an *ex post* vision, the farming system and decision rules will be considered as resilient in an identified environment.

For example, the objective of local self-sufficiency makes the systems sensitive to the variation of the land natural properties, mainly climatic events. In 2004, we built a decision rule to choose winter inter-crops species, following three objectives: producing a high level of biomass, competing weeds and being mulched, as green manure, using as little energy as possible. Predicting a systematic freezing during winter, we made a trade-off, choosing systematically frost-driven crops, for a self mulching during winter, even if they did not maximise biomass production and weed competition. Cool and wet winter 2006 made us reconsider the decision rule, adding “if the winter is cool, then a mechanical destruction is required”. This unpredictable event made us also reconsider the trade-off and the systematic choice of frost driven crops.

The pluriannual experiment at the system scale also allows us to evaluate the consequences of different strategies and decision rules on the biological sub systems. In the MCDS, we identified a source of commercial flexibility for the system, which is to be able to choose between *(i)* feeding cows in winter with cereals grown in the system and *(ii)* selling the cereals. The question is then: Is cow plasticity high enough to face variations of diet quality (amount of cereal in the diet) from one year to another? Will those variations have some consequences on the dairy herd demography (culling strategy…)?

Prospects: towards indicators based on operational functioning of production systems

Prototyping pluriannual farming systems and defining *ex ante* decision rules might lead to build decision trees and to choose piloting indicators that take system complexity into account. Decision trees coupled to piloting indicators might be an interesting way to coach farming system changes towards more sustainability. Studying flexibility might enable creating indicators, mainly qualifying system sustainability based on farming practices. This would be a way to complete current indicators which mainly qualify system sustainability on the base of their environmental, social and economic impacts. Indicators based on practices might make it possible to identify, to question and to renew practices towards more sustainability.

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