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Objectives

Sustainability of agriculture invites us to a multi-criteria approach. Considering environmental sustainability of farming systems, many criteria can be taken into account like water and air quality, soil fertility, biodiversity, energy consumption etc, more or less scientifically known. The research team of Mirecourt INRA station prototypes farming systems building a partnership with the nature (agriculture insuring the reproduction of natural resources). We postulate that the partnership will be obtained by prototyping agricultural systems structured by territory properties and self-sufficient at an agricultural territory scale (Mignolet et al., 2004). Self-sufficiency at a local scale will be achieved by *(i)* the adoption of organic agriculture rules, promoting low-input and uncontrolled low-output flows and *(ii)* by connecting such farming systems in a local area in order to maintain the integrity of the local resources. In this paper, we present the method used to prototype multi-objectives farming systems and the connected prototypes of farming systems obtained.

Prototyping multi-objectives systems

Sustainable farming system includes various conflicting aims which have to be solved within the farm system and in its articulation with other systems. Prototyping method follows three iterative steps consisting in *(i)* designing production systems according to the defined objectives they have to achieve, *(ii)* evaluating systems by experimentation at the system scale and *(iii)* modelling biotechnical and operational processes implicated in the experimented systems operation.

In Mirecourt INRA station, system designing was done, using a method adapted from Vereijken (1997), by consulting a multi disciplinary group of scientific experts. The main objectives for both prototype were: *(i)* preserve resources like water and air quality and fossile energy, *(ii)* be productive *(iii)* use environmental compounds, like animal and vegetal biodiversity and soil fertility, for agricultural systems purpose. The experts had to disaggregate main objectives in sub-objectives targeted on sub-systems or managed units of the global systems, approaching a more operating level of organisation. Then, they classified these sub-objectives by a determined method of notation. This classification determined *(i)* the relative importance to give to each objective while determining decision rules used to manage the prototypes and *(ii)* the weight given to each criterion evaluating the achievement of the objectives in the global evaluation of the prototype.

Designed systems are evaluated in an experiment at the system scale. The two connected dairy systems tested since 2004 in Mirecourt experimental station 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). In order to design those systems according to the above three objectives, the 240 hectares of the experimental site were considered as a small agricultural territory. Considering the local economic context, farming systems are connected by *(i)* their design, using optimally the heterogeneity of the natural resources while assuring their sustainability *(ii)* their functioning, facing the lack of inputs at a single system level by local and equivalent exchanges between the two systems and smoothing the curve of the sales of animal products (milk, calves) at the small region scale. Farming systems are managed following constant decision rules (Sebillotte and Soler, 1990; Reau et al., 1996) and evaluated. Since 2004, experimental evaluation focuses on *(i)* biotechnical processes implicated in the prototypes and *(ii)* convenience of the systems and the decision rules used to manage them.

The instrument of agro-ecological evaluation was built considering pedo-climatic properties of the fields, demographic and genetic properties of the cattle, and practices already implemented and foreseen to manage them. It relies on basic measures on the dairy herd (milk production, growing and reproduction performances etc.), and on 76 sampling plots of 900 m^2 in the fields concentrating agronomic and environmental measures (crop yield, vegetal biodiversity, carabidae populations etc.). Evaluation at the sub-system scale by building analytical trials in the systems can be carried out.

Convenience of the systems is evaluated through the convenience of decision rules used to manage them. This relies on regular meetings aiming at decision making on technical aspects between scientists, pilot of the prototypes and technical staff. Debates and arguments are noticed and can be analysed in order to identify an eventual and/or a necessary evolution of the cognitive action model (Sebillotte and Soler, 1990) used to build a decision rule. So we focus on the constance of *(i)* the objectives, *(ii)* the criteria used by the pilot and the staff to evaluate the achievement of the objectives and *(iii)* decision rules applied to achieve the objectives.
Modelling aims at an *ex ante* evaluation of the sustainability of the overall system connected or not to other systems, and of sub-systems or management units. *Ex ante* sustainability assessment can be handled by multi-criteria decision aiding (MCDA) methodologies (Sadock *et al.,* 2007). This kind of model allows virtual experimentation. Virtual experimentation is complementary to classical experimentation (Meynard et al., 2001): *(i)* designed systems (by groups of experts) can be classified and selected on the base of their sustainability, evaluated *ex ante* using interactive simulations, *(ii)* systems sustainability can be evaluated rapidly in different contexts. Classical experimentation is necessary to estimate some parameters of the model (depending on local context etc.) and to test the accuracy of the model in predicting the performances of the systems or sub-systems.
Since this year, we are elaborating an indicator-based MCDA model developed within a decision support tool called DEXi (Bohanec, 2007) for *ex ante* evaluation of the sustainability of grazing dairy systems. In this kind of model, system sustainability is decomposed in less complex sub-problems down to the level of input attributes representing the sustainability criteria of the system. Criteria can be expert-based or scientific indicators. Evaluation of the systems sustainability is performed by an overall aggregation that is carried out from bottom to the top of hierarchy according to its structure and defined utility functions (Bohanec, 2007). Utility functions used for each level of aggregation are based on transparent and qualitative decision rules (Sadock et al., 2007).

Discussion/Prospects:

The prototypes design could have be done using model based methods taking into account expert knowledge by *(i)* systematic design and *ex ante* evaluation methods like Rotat and Farm Images (Dogliotti et al., 2005), or *(ii)* interactive simulation, involving a group of experts, using for example an indicator-based MCDA model. But until now, no systematic design and *ex ante* evaluation model or MCDA have been built to evaluate mixed-crop dairy system sustainability. We plan to build an indicator-based MCDA model for *ex ante* evaluation of the sustainability of innovative mixed-crop dairy systems.
Prototypes evaluation is set in an experimental station because it allows a high pressure of measures on a prototype and an analyse of the evolution of the cognitive action model. But, prototyping in commercial farms will be necessary in order to *(i)* evaluate the prototypes in different socio-economic and pedo-climatic contexts and *(ii)* evaluate the convenience of decision rules in different cognitive action models. By increasing the field of validity of the prototype, prototyping in commercial farms will also contribute to the improvement of the MCDA model built on the basis of accumulated knowledge.

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