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Is « bio-economic » farm modelling of any help for farming system design?

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1 Introduction

Many innovations at cropping system level impact the whole farm system by changing the flow of farm resources across farm activities. Using farm models has increasingly been proposed for assessing the feasibility of prototypes of cropping systems at farm level, and evaluating their impacts on household food production, farm income, and the environment. Such models are often called bio-economic model as a way to stress the mixing of knowledge about the biophysical and economic aspects of farming (Janssen & van Ittersum, 2007; Thornton & Herrero, 2001). *A priori*, one should not expect accurate predictions from these coupled bio-economic models, because of their complexity and the difficulty of measuring certain key input variables, such as labour availability for the different farm and off-farm activities, family income, and intra-farm consumption of agricultural products. This type of models can rather be used to explore 'what if' scenarios and to understand their outcomes including their inevitable uncertainty. In this paper, we review our experience with bio-economic farm models as virtual test benches for evaluating "cropping systems ideotypes" (CSI), i.e. idealized cropping systems proposed as alternatives to existing cropping systems, for increasing farm income and production or for reducing negative impacts of farming on the environment. Six published case studies are used (list of papers available at http://agents.cirad.fr/index.php/Krishna+NAUDIN/bio_economic_farm_modelling). The objective is to examine to what extent the models developed fulfilled their purpose of evaluating prototypes of cropping systems for farming systems design.

2. Materials and Methods

In 3 out of 6 case studies ('Madagascar', 'Brazil-CA', and 'Vietnam') the CSI were conservation agriculture options designed for low income family farms. In two other case studies, 'Senegal' and 'Brazil-Conv', the CSI were conventionally intensive cropping systems as an alternative to low yielding current practices. In the 6th case, 'France', CSI were options designed to reduce ground water pollution by lixiviated N. In all the case studies, we used farm models based on the 'Optimization Under Multiple Constraints (OUMC)' approach, in which an optimization procedure is used to find the set of crop, livestock and off-farm activities that best fits the objective of getting the highest farm income subject to constraints relative to seasonality of activities, the necessity to satisfy the family's basic needs (in food, clothes, health and education) throughout the time period covered by the simulation, as well as constraints relative to the farm's resources in land, labour force, equipments, and cash money. In each case study, a regional assessment of the diversity of farms was first established based on relatively large surveys. Table 1 shows the differences between cases regarding farm structure.

Table 1. Main characteristics of farms modelled in the case studies

Case studies	Predominant Farming system	Farm size (ha)	Number of family members	Number of workers	Total household income (€/capita/year)	Off-farm income (€/capita/year)
Brazil-Conv	Mixed crop livestock in transition toward intensive dairy farms	5-120	2-10	1.5-3.75	40-8000	0
Brazil-CA		16-51	2-4	2-3.8	800-6000	0-560
Vietnam	Mixed crop livestock systems in transition from subsistence to market oriented farms	0.7 – 4.7	5-12	2-7	20-400	0-200
Madagascar		2.5-3.5	5	6	5-800	0
Senegal		3.5-16	12-25	4-10	100-300	0
France	Mixed arable farms	100-120	3-5	0.25-1.1	25000	0

In 4 out the 6 studies, two typical farms were then selected within each of the farm category identified, and they were modelled thanks to a more detailed questionnaire applied to each individual farm. In the two other studies ('Senegal' and 'France'), each farm category was modelled using data of the survey averaged over the category. In all the case studies, model calibration was carried out to ensure that the model reproduced well the observed farm plans when using 'baseline simulations' in which the studied CSI were not incorporated into the list of options available to the simulated farm. Then, various scenarios were simulated in which CSI were included into the list of options, and changes in the economic environment of the farms were explored, such as changes in the prices of input or output, in the availability of credit or other financial tools, or introduction of subsidies of several kinds. Differences between studies in term of methodology were limited to the extent to which biophysical models were used to produce data relative to cropping systems and to minor differences in the optimization algorithm used. However, the level of complexity of the model varied greatly among cases, depending on the need to account for crop-livestock relationships, for the dynamics of farm performances over time, or for risks related to yield or price variability.

3 Results – Discussion

The main results are summarized in table 2. For several case studies, we found that even relatively uncertain model parameters or a highly simplified model structure allowed to draw robust conclusions on the feasibility of the locally studied CSI. The robustness of the conclusion was less dependent on the case study than on farm type within case studies. Typically, simulated farm plans were particularly robust for farms with strong labour constraints. In such case, the model prediction about rejection or adoption of CSI is not to be taken as an anticipation of what will occur in the real world. Rather, it provides insight on the economic relevance of the CS at farm level. When the model predicts rejection for farms with very low income, however, it is very likely that the technique will not be adopted by real farmers, who are not expected to make decisions putting at risk the daily subsistence of their family. When model outputs were less robust (i.e more sensitive to uncertainties on key inputs), they were still useful for qualitatively identifying the main factors at farm and field level determining the economic relevance of adopting the studied CSI. They also helped in identifying knowledge gaps that should be addressed for improving the reliability of quantitative assessment of the feasibility at farm level of studied CSI. Often, these gaps relate to the availability of data that quantify the agronomic performances of CSIs in the biophysical and socio-economic environment of the case study.

Table 2. Summary of results per case study.

	CSI tested	**Model complexity (*)**	**Data on CSI performances**	**Typical Result in terms of FSD**	**Typical gaps in knowledge identified**
Brazil-Conv	More intensive maize systems (cultivar, fertilizer, mechanization)	2/4 :S-R-LB	Ad hoc crop model calibrated and validated on site	Identification of soil constraints making dairy specialization too risky for certain farms under current economic environment	
Brazil-CA	Conservation agriculture	4/4 :D-R-LC	On-farm and on-site trials	CA ideotypes refined per farm types	Agronomic / environmental performances of CA
Vietnam	Conservation Agriculture	1/4 : S-NR-LB	On-farm and on-site trials	CA not appropriate for most farm types, subject to further studies for others	Long term Agronomic / environmental performances of CA
Madagascar	Conservation agriculture	3/4 : D-NR-LC	On farm surveys and trials	CA systems with fodder crop beneficial for dairy cow farmers. Fraction of biomass used for soil protection against erosion likely to decrease when price of milk increases.	Agronomic / environmental performances of CA
Senegal	More intensive cereal cropping systems (fertilization)	2/4 : S-R-LB	Ad hoc crop model calibrated and validated on site	Drought insurance may entail crop intensification but subsidies to insurance are less effective than subsidies to credit or than direct cash transfers to farmers for increasing the simulated farm income	Agronomic / environmental performances of crops under highly variable rainfall. Nutrient fluxes between livestock and crops.
France	Lower N lixiviation systems	1/4 : S-R-L0	Ad hoc crop model calibrated and validated on site	The cross-compliance restriction associated to nitrate directive needs to be high to incite farmers to adopt CSI	Suitability of bio-economic modelling for co-assessment and co-design of cropping systems.

(*) Model complexity is described using a 1 to 4 scale and a string chain accounting for Dynamic (D, 1) or Static (S, 0) approaches, plus the integration of Risk (R, 1) or not (NR, 0), plus the level of details of the relation between livestock and cropping systems (LC: detailed, 2; LB: basic, 1, L0: none, 0)

4 Conclusions

Bioeconomic farm models should not be seen as a way to predict adoption or rejection of innovative cropping systems by real farms, but rather as a way to better identify (i) gaps in knowledge about the agro-environmental performances of such innovative cropping systems that are critical for comparing them with current practice from the point of view of a farm, and (ii) the key factors determining the feasibility of such systems at that scale. In that sense, bioeconomic farm models are a very effective way to assemble available knowledge at field and farm scale for identifying the conditions at which strong changes in cropping systems may take place.

References

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