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BIOECONOMIC MODELLING: IS THERE ROOM FOR SEAMLESS INTERDISCIPLINARITY ?

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Résumé — A partir de trois études de cas de modélisation bioéconomique d'exploitations agricoles, l'objectif de cette communication est de tirer des leçons concernant le défi de l'interdisciplinarité entre sciences biophysiques et sociales. Le résultat des études de cas illustre le bénéfice qui peut être attendu de ces études bioéconomiques. La communication se base sur ces expériences pour discuter des difficultés provenant de l'interdisciplinarité. Certaines de ces difficultés peuvent être maîtrisées relativement simplement en prêtant attention à la construction du respect mutuel et de la confiance entre membres de l'équipe, ou plus généralement en reconnaissant que si le travail est plus difficile il faut lui allouer davantage de ressources et de temps. Mais l'interdisciplinarité peut introduire des problèmes de pouvoir plus subtils à manipuler, bien que des cadres théoriques soient disponibles pour cela. En tout état de cause, prétendre réussir des études interdisciplinaires « sans couture », simplement grâce au choix des bons outils et ressources humaines, risque fort de produire de nombreuses cicatrices, au moins dans la mémoire des participants.

Mots clés : systèmes de production, systèmes de culture, multidisciplinarité

Abstract — From a set of 3 actual case-studies involving bioeconomic farm modelling, the objective of the paper is to draw lessons regarding the challenge of interdisciplinarity between biophysical and social science. The results of the case studies illustrate the benefit that can be expected from these bioeconomic studies. The paper then builds on these experiences in order to discuss issues arising from interdisciplinarity. Some of these issues can be overcome relatively simply by paying attention to the construction of mutual respect and trust within the team of scientists, or more generally by recognizing that if it is more difficult, then more means and more time should be devoted the job. But interdisciplinarity may bring issues of power that are more subtle to handle, although theoretical frameworks are available for doing so. Anyway, pretending to achieve interdisciplinary studies seamlessly, just thanks to the use of the right tools and human resources would most probably result in numerous scars at least in the memories of the participants.

Key words : farming systems, cropping systems, multidisciplinarity

INTRODUCTION

As many key issues of the times concern coupled social-biophysical systems, scientists are urged to practise interdisciplinarity (Ewel, 2001). In the domain of agricultural science, a typical case is "bioeconomical modelling", using farm decision models. These are well known tools for studying the impact of agricultural policies, technological innovation or more recently climate change, on production systems. Analyzing human decision belongs clearly to social science, but it is more and more acknowledged that the relevance of farm models strongly depends on the way they account for the biophysical processes involved in farming. Works discussing interdisciplinarity from an epistemological perspective have highlighted many difficulties explaining why it remains challenging especially at the intersection between social and biophysical science (Klein, 2008). It is then not surprising that only few "bioeconomic studies" have been performed by truly multi disciplinary teams. In most cases, indeed, scientists from one domain use simulation models from the other domain as libraries containing the knowledge they need, rather than directly collaborate with scientists from the other domain. This approach, however, might not be relevant since it implies the use of concepts and models without the adequate background about their validity domain and limitations. Alternatively, some scientists pretend to develop skills in both domains, with a risk of failing to be peer-recognized in any of them.
In other cases, when scientists of both domains are jointly involved in a study, issues arising from interdisciplinarity are generally not reported in papers, as if interdisciplinarity has been achieved seamlessly. Our paper first reports actual case studies in order to illustrate the benefit that can be expected from bioeconomic studies. Then it builds on these experiences in order to discuss practical issues arising from interdisciplinarity between biophysical and social science and to propose ways to reduce their potentially negative impacts on the quality of research.

1. METHOD

Three case studies were used in which research questions were involving both field and farm scales, and were requiring (and aiming at producing) knowledge on cropping systems, livestock systems, farming systems and household decision systems. Farm decision models were designed specifically for each study, tailored to the specific question addressed, nevertheless using the same general approach of mathematical programming models (Hazell and Norton, 1986).

1.1. Questions addressed in the case studies

1.1.1. Ex-post analysis of contrasted production systems dynamics, central Brazil

The first case study (case 1) took place in the rural district of Silvânia, in the *Cerrados* of central Brazil, where for over a decade a R/D project observed, and contributed to an agrarian revolution. Indeed, most family farms of Silvânia, which were subsistence-oriented and maintained extensive cropping and livestock systems turned predominantly into highly intensive, specialized dairy farms within that decade. These farms adopted technologies such as: soil reclamation, animal genetic improvement, fodder production, artificial pastures. It resulted in a dramatic increase in farm revenue, net income per worker and more generally family welfare. Apart from the prerequisite of market opportunity for dairy production and the pre-existence of a collection/ conditioning chain for milk in the region, a key factor determining this revolution was the collective action of farmers: building associations, they obtained credit from the public banking system and reduced the transaction costs for commercialising their products and buying their inputs (Bainville et al., 2005).
Many farms, however, remained out of this revolution (hereafter "undeveloped farms", as opposed to "developed farms" which experienced the revolution depicted above).

Understanding this disparity was critical, as potentially enlightening the broad question of the determinants and constraints of small scale farms development in developing countries. The hypothesis tested in this case study was that soil constraints were involved in the difference between developed and undeveloped farms, possibly increasing the risks associated with the intensive maize crop and thus with the intensive livestock system for which maize was a key production factor (Affholder et al., 1996).

1.1.2. Ex ante assessment of innovative cropping systems

Substantial initiatives are under way in the tropical world to develop and promote Direct seeding Mulch based Cropping Systems (DMC) in an attempt to improve staple crops productivity and sustainability (reducing soil erosion, improving crop nutrient and water balances and other ecological services). DMC typically introduce major transformations in the allocation of farm resources such as land, labor, cash and capital. Some DMC options have been adopted by large-scale mechanized farmers, especially in America and Australia, but seldom by resource-poor farmers in the developing world. Recent reviews suggested that many constraints at field, farm and community level are involved in this rejection of the technology by resource poor farmers (Erenstein, 2003; Giller et al., 2009).
In the next two case-studies, we assessed the potential economic attractiveness, and farm-level constraints to adoption of maize-based DMC for contrasted farm households located in Central Brazil and in mountainous provinces of Vietnam.
In both cases, we assumed that a necessary, but not sufficient, condition for DMC adoption is that DMC are economically sound at farm level. Symmetrically, DMC not economically sound at farm level was assumed a sufficient (but not necessary) condition for rejection.
In Bac Kan province (Vietnam, case 2), most farmers have land along sloping uplands where they cultivate upland rice, maize and cassava, as well as land on valley floor or irrigable terraces were they grow irrigated rice. Off-farm activities provide an additional income, significant or tiny depending on labour market and labour force available in the farm. Livestock systems include mostly pig raising, with maize produced on the farm being one of the feeding sources, and one or two buffaloes are kept to provide draught power for ploughing paddy fields. DMC were proposed to these farms as a way to avoid soil erosion on sloping land.
Seven farm types were considered, with differences regarding the biophysical environment of the farms (soils and climate), degrees of integration to market, and the following ratios: land per capita, land per worker, upland over lowland plus upland area, workers over mouth to feed.
The case in central Brazil (case 3) took place in the rural district of Unai, located at 160 km south east of Brasilia. The case is very similar to Silvânia, in terms of the biophysical environment as well as regarding the dynamics of farming systems. There also, family farms have been rapidly evolving from subsistence-oriented, highly diversified farms towards more specialised, market-oriented dairy farms. The specificity of the case comes from the fact that the study focused on small farms relatively recently created and extremely resource-poor; the *assentados* established during the last decade in the framework of an agrarian reform. We also considered several farm types corresponding to various positions along the trajectory between subsistence oriented, just installed farms, and dairy specialized farms, positions which resulted mainly from differences in time since installation, the initial assets of the household, and the access of farms to markets, mainly for milk. DMC were proposed here as a way to reduce soil erosion on sloping land, as for the Vietnamese case, but also to reduce farmers' dependence to the market of rented farm machinery, to reduce fuel consumption, and to provide an extra fodder source via cover crops.

1.2. Models

For all these three case studies, we used Optimization Under Multiple Constraints (OUMC) approach, based on a bio-economic farm model developed using mathematical programming

techniques (Hazell and Norton, 1986). In this approach, mathematical equations describe the farmer's objective (an utility function, namely annual farm income in our studies), the inputs and labour force required for each farm activity and each biophysical environment considered in the model and their expected production (i.e. the activities technical coefficients), and a set of constraints regarding the availability of production factors over seasons, the rules of family labour allocation, the satisfaction of food and basic needs /or preferences, the maintenance of inter-annual variations of income within certain limits corresponding to a certain risk aversion of farmers, etc …The optimizing algorithm selects the set of farming activities and their allocation across land and seasons that best fits the objective of farmers subject to those constraints and given the assumptions made on the performances of the elements of the production system. A specific model was built for each case study, differing in the sets of activities and biophysical environments considered and their technical coefficients, as dictated by the farming systems and the specific questions addressed in each case. The models developed for the two case studies in Brazil both included a relatively detailed description of the livestock system and accounted for risks resulting from inter-annual climate variability. The livestock component of the model used for the case study in Vietnam was much simpler and risk issues were ignored, but the model was accounting more precisely for off farm activities, food security constraints of the households, and the impact of fallow duration in the productivity of certain cropping systems. One important limitation of the models in the three cases was that they did not account for the dynamics of agronomic performances of cropping systems over time, as a possible result of soil degradation or improvement under aggressive or environmentally sound cropping systems, respectively.
These models were first validated by comparing simulated to observed farm plans of actual farms. In cases 2 and 3, these baseline simulations were performed without incorporating DMC into the list of possible farm activities. Then several new runs of the models were performed in order to explore the impact on farm plans and income of scenarios of (i) changes in the sets of farm activities available to farmers (introduction of DMC in cases 2 and 3), (ii) changes in the economic environment of the farm (prices of inputs and outputs, of labour force, presence of subsidies supporting the adoption of DMC in cases 2 and 3, (iii) changes in farmers' risk aversion, (iv) changes in the biophysical environment of farms (increase or decrease in yields of crop or livestock systems).

Model development and simulations at farm level were performed under the responsibility of agricultural economists (Vietnam, Silvania) or livestock systems specialists (Unai).

1.3. Data acquisition

Information about farmers' goals, farm structures, and the technical coefficients of most activities was obtained through farm surveys carried out under the responsibility of the agricultural economists. Field agronomists were in charge of providing technical coefficients specifically for crop activities, using trials, monitoring of networks of farmers' fields, and (in cases 1 and 2) crop simulation models built, calibrated and validated using data from these trials and field networks. In the three case studies, the field work in agronomy was carried out over three agricultural campaigns.

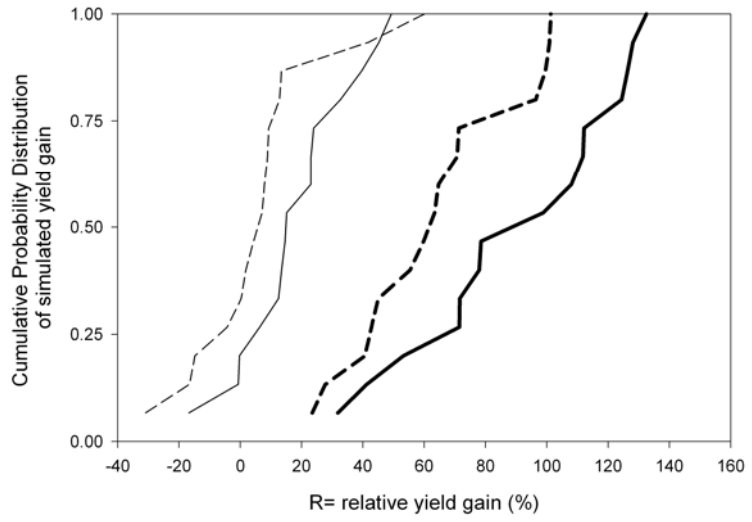
2. RESULTS

2.1. Results of the case studies

In Silvânia (Brazil, case 1), the crop model simulations of maize yields over a series of 21 years of climatic data showed that the yield gains permitted by intensification were highly dependant on the climatic conditions of each year, the soil type and the quality of crop

establishment operations. The more constraining were both the soil and the way farmers have access to machinery, the smaller was the expectancy of closing the yield gap a given year by increasing N fertilization and sowing density (figure 1).

Figure 1. Probability that the relative yield gain is lower than a given value R, study case 1.



Simulation over 21 years of weather data. Thin lines: SC soil, thick line: DL soil.
Continuous line: well mastered intensification, $R=100.(Y_{IcsW}-Y_{Ecs})/Y_{Ecs}$
Dashed line: poorly mastered intensification, $R=100.(Y_{IcsP}-Y_{Ecs})/Y_{Ecs}$
where Y_{Ecs}, Y_{IcsW} and Y_{IcsP} are yields simulated for cropping systems Ecs, IcsW and IcsP respectively.

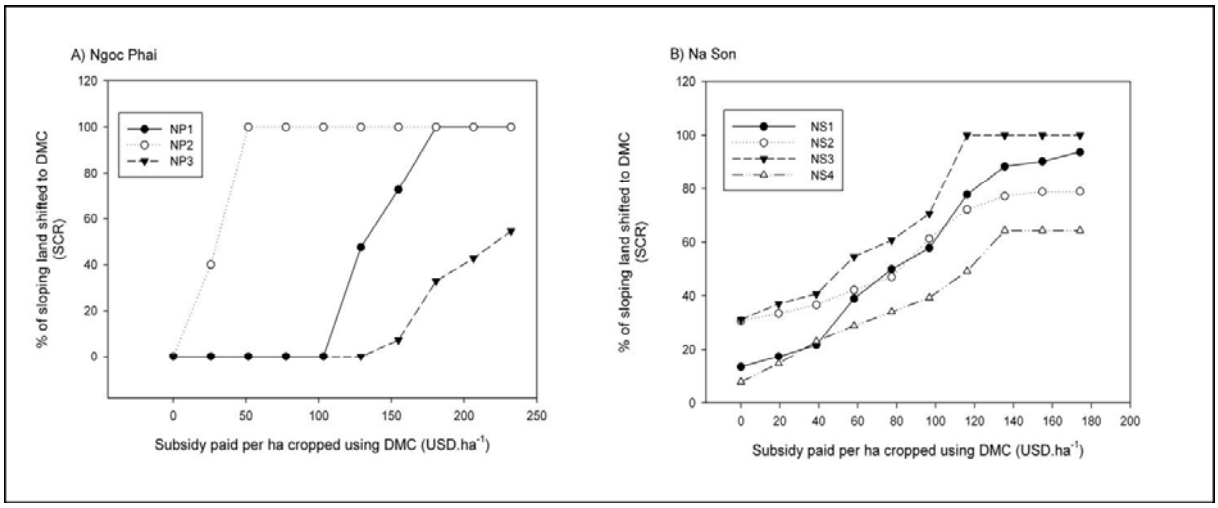
(Adapted from Affholder et al., 2006)

On the "SC" soil type (Stony Cambisol), there was a probability of circa 0.2 that yield is not increased when shifting from Extensive cropping system Ecs to intensive cropping system Ics. Details (not shown) of the simulation data indicated that this was due to a high frequency of strong water stresses on these soils with low water storage capacity. This probability rose up to 0.5 when considering poorly managed farm machinery, as a consequence of the fact (data not shown) that under this context, delayed sowing (relatively to last tillage operation) and inadequate seed depth jointly contributed to low stand density and consequently high weed pressure (Affholder et al., 2003). Contrastingly, on the much more favourable deep latosols (DL), there is a null probability that yield increase is below 30% of yield obtained under extensive system, and close to one year over two farmers can expect a doubling of their maize yields when shifting from extensive to intensive systems on these soils.
The results of farm decision simulations were in agreement with the observed dynamics of production systems. Farms relying, for their maize production, on constraining soils such as the stony cambisols, would not develop toward dairy farms, in the simulations with the farm decision model, whereas the model predicted the development of farms with significant area on deep, amended latossol or similarly favourable soils. These results were thus in support of the hypothesis that the biophysical constraints and their variations across Silvânia district were sufficient conditions for certain farms to reject intensification and specialization strategies, even with unlimited access to market and credit and relatively low risk aversion (Affholder et al., 2006).

In the case studies 2 and 3 the simulated choice of adopting or rejecting the innovative cropping systems was variable across farm types and environments. In Vietnam (case 2), with manual cultivation on slopes, adoption was in most farm types hampered by extra requirements of the innovative cropping systems in labour and cash, as compared to

conventional cropping systems. Changes in labour and cash requirements of DMC were explored, corresponding to possible adjustments in the DMC technique such as reduction in the amount of mulch and fertilizer used, and increase in the use of herbicides (part of the mulch biomass being used as a barrier against weeds, reducing the mulch used, and hence the labour force required, would have to be compensated by an increased use of herbicide). However, none of the practically feasible adjustments of DMC provoked a change in the rate of use of DMC in the simulated farm. The amount of subsidies that would have to be paid to simulated farmers for them to convert all their conventionally managed sloping land into DMC measures the "unattractiveness" of DMC and its variations across farm types with a group of farms were labour constraints predominate (figure 2A) and another (fig. 2B) were cash constraints predominate (Affholder et al., 2010).

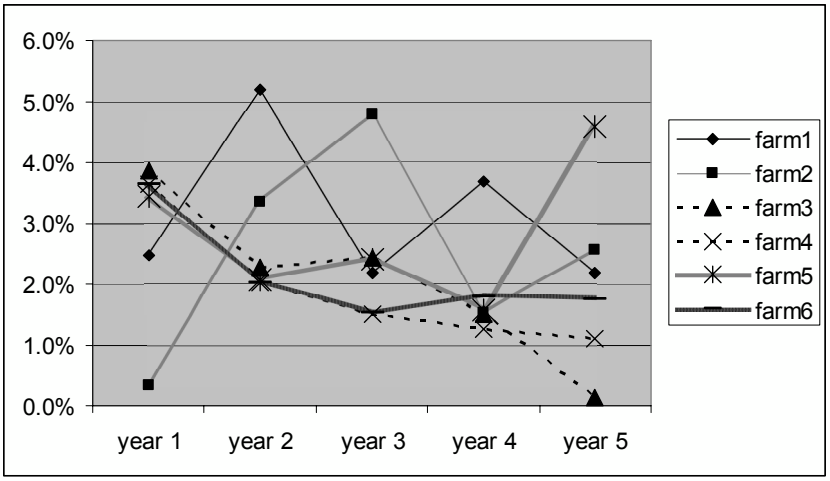
Figure 2. Sensitivity of simulated adoption of DMC to subsidies, study case 2



(Affholder et al., 2010)

In Unai (case 3), farm simulations suggested that DMC were slightly more economically attractive than conventional systems thanks to a significant reduction of cash requirements permitted by the abandon of ploughing. The farm model proved highly sensitive to small changes within the confidence interval of the fodder value of cover crops. These fodder values of the cover crops were relatively uncertain in this context of cultivation under DMC, compared to what is known about these crops when being cultivated as pure fodder. Additional measurements and analysis, currently undergoing, appeared thus necessary for completing the study in order to conclude on the interest of DMC with cover crops for the *assentados* of Unai.

Figure 3. Annual deviation of net profit with the introduction of the DMC system with fodder cover (comparison with the baseline scenario in %), study case 3.



2.2. Interdisciplinary issues

2.2.1. Some naïve confidence at our first steps

Most of us in the team started working together about 15 years ago at Silvânia with case 1. At that time we had freshly acquired a relative autonomy in deciding which question to address and which collaborations to develop for addressing these questions. "Bioeconomic modelling" studies were still rare. We had previously developed skills in the emerging modelling tools of our disciplines. We were extremely confident in the power of modelling for integrating knowledge from different disciplines and scales, and absolutely naïve about the possible problems associated with interdisciplinarity. In all the case studies of this communication, the questions were brought mainly by field agronomists, aware that issues arising at farm level and above may determine farmers' strategies at field level, recognizing that specific skills were required to address questions at these levels, and requesting the contributions of scientists having such skills. The team of 4 scientists that we constituted for the first study evolved during the following 15 years, with its hard core, some abandons and some new recruits, the size ranging between 3 to 8 scientists. It remained informal throughout, i.e. it never matched any administrative unit of any kind, and resources mobilized for our projects had to be distributed across several research units.
The relationships among us were not free of some kind of frustration and tension. We assume here that this kind of roughness in the relationships had something to do with the interdisciplinary nature of the work much more than with the individual personalities.

2.2.2. Issues objectively turning the job more difficult.

Under this title falls all what we identified as objectively reducing our efficiency in publishing our work as compared to our activity at the core of our disciplines.
We immediately faced high transaction costs between the numerous administrative entities involved in the work, our institution being mainly organised in discipline-centred units. An alternative on this latter point would have been to construct a specific administrative entity matching the contours of our team, but this would probably have cost us at least as much time as spent in managing our activity across several units.
We also soon experienced the necessity to allocate time for learning the language and culture of the other disciplines. This does not only mean learning new terms. Indeed there can be conflicting understandings of shared vocabulary (Wear, 1999), and this is particularly treacherous because a conflict has to occur in the first place for this to be identified as an issue. Furthermore, and especially in occasions where one discipline is represented by one individual only, the lack of experience may lead some to believe that personal tempers are the cause of the conflict.
It was generally not possible to have multi-voices speeches when presenting our work in seminars and lectures, not so much as a result of some kind of conservatism in the scientific community, but principally due to logistical constraints, especially in our team composed of scientists posted all over the world. As a consequence, the speaker had to master much more concepts than when he/she deals with matters from his discipline, and still exposed himself to the critique of specialists from the other disciplines, with little chance to provide relevant answers or to take the relevant benefit of the critique. An additional risk is that the speaker unintentionally draws in public some conclusions that would not be endorsed by his colleagues of the team. The more each member of the team invests in learning the concepts and tools of the other disciplines involved in the work, the better for avoiding the risks mentioned above, but there is obviously a need for a compromise between such investment and the use and maintenance of the skills acquired in the discipline of origin of each one. Failing to do so would expose scientists to the risk that most of their work is not recognized as contributing to any clearly identifiable scientific domain (Naiman, 1999). We must admit,

however, that we don't know much about the proper setting of the cursor between these two opposed risks.

Regarding culture, throughout our studies there happened to be great differences between field agronomists and farm economists in their relation to time and project's life cycle. Field agronomists claimed that data collection would be valueless unless the data cover at least two agricultural campaigns, in order to capture a minimal amount of the interannual variability of crop performances. In case studies 1 and 3, model calibration demanded additional data collection campaigns in order to improve the capacity of the crop model to predict the variations of crop yields across environments and technical management. In contrast agricultural economists needed only a few months for completing their farm surveys and get enough data for "their part" of the farm models. Changes in the economic environment of the farms, especially in emerging countries such as Brazil and Vietnam, as well as changes over time in the perceptions of this environment by farmers, limit the validity of farm decision models to a few years, whereas the validity of most components of a crop models expands over a much larger period of time. For our first case study, our lack of experience on this disjunction of the production cycle in the two domains resulted in a project getting soon completely out of its Gantt chart, and this probably contributed to the very low number of articles published from this study.

From his own experience in contributing to and managing interdisciplinary studies, Naiman (1999) described many difficulties similar to those we mentioned above, and suggested a set of guidelines for minimizing their impact on the quality of science (and the relationships between scientists, obviously). These guidelines converge mostly towards management principles favouring mutual respect in the team, including at the stage of choosing members of the team willing to jointly assume leadership and responsibility. This suggests that a team constituted as a decision from the hierarchical management is not necessarily the best formula for interdisciplinarity. One other particular consequence for institutions willing to develop interdisciplinary studies is that the way individual and/or collective performances are assessed should at least not discourage efforts in that direction. The incautious use of the raw number of peer reviewed papers per individual and year will not completely extinguish interdisciplinary studies only because there always are a number of scientists who care less for their consideration by others than for what excites their curiosity. But if institutions count on this, then what are those indicators made for ? Incidentally, but this deserves to be mentioned given the tendency of research funding agencies promoting big projects, small teams are probably more able than big ones to cope with the specific issues of interdisciplinarity. There might be a threshold, however, below which debates between disciplines are likely to turn into conflicts among persons.

2.2.3. Where the fruits of interdisciplinarity are potentially poisonous

The results of the first study in Brazil were rather disappointing for the agricultural economists of the team, who were expecting social and economical constraint to predominate over biophysical constraints in farmers' strategies. In the two other studies, field agronomists were the more surprised by the results especially those obtained in Vietnam, since they were expecting the innovative cropping systems to be economically attractive to the well informed, rationale farmers that were idealized in the farm models. The way interdisciplinarity brings surprise is where most of its added value resides. But at the same time it generates a series of questions regarding the quality of the work of each member of the team that are potentially threatening their willing to further take part of the adventure.

Another illustration of that potential threat is provided by the fact that we were not able, in the case studies on DMC adoption, to account for the evolution over time of the performances of cropping systems. This limitation of our models was indeed a frustration for everyone, since it prevented us to determine whether the low attractiveness on the short term of some DMC options would be counterbalanced by better performances, relatively to conventional cropping systems, on the longer term. But furthermore, this limitation in the power of the biophysical models was a surprise for the agricultural economists of our team. Actually, this

could surprise many biophysical scientists as well, since articles are not uncommon in which models are used to predict the behaviour of a particular biophysical system over the next 50 years or beyond. But arguing that we are not confident enough in our model to use it for long term predictions is probably much easier in front of a circle of biophysical scientists who are not likely to blame you for any excess of honesty on that point, than within a circle of agricultural economists, where some might suspect your concerns for rigour to hide lacks in your modelling skills.

The disjunction in the production cycles of the two domains was also a medal with two faces. On one side it brought some comfort to every one, since it allowed us to alternate the more risky phases of truly collaborative interdisciplinary tasks, with periods during which we were dealing with activities closer to the core of our respective disciplines, with more opportunities for each individual to build his scientific credit vis-à-vis his peers. But on the other side it strengthened the centrifugal forces that repulse scientists from the interface between disciplines, forces against which at least some have to struggle for the project to deliver its expected outputs. Perhaps as a consequence of this, many of us, whatever their discipline, felt at a moment or another, an asymmetry or a kind of hierarchical relationship between disciplines. For instance, in the two studies in Brazil, field agronomists felt the pressure of farm economists looking forward the moment where at last, after a series of experiments / modelling / validation loops at field scale, their colleague would provide them with sound data to use in the model at farm scale. The question of “how sound” the data should be echoed with “how soon” they would be available.

In our kind of simulation of farmers’ decisions, the question of “how sound” is the question of the sensitivity of the simulated decision to errors in the input variables of the farm model. In the studies in Brazil (cases 1 and 3), the farm model proved to be highly sensitive to some of its input variables that were actually output variables of the crop model, with an initially wide confidence interval. Reducing this confidence interval justified a series of modelling loops at field level that had not been anticipated. An alternative would have been to publish that the biophysical model was not precise enough for the analysis at farm level to provide robust conclusions. This might have satisfied the biophysical scientists as justifying more efforts in their disciplines, but would probably have frustrated the agricultural economists who had already paid their tribute to interdisciplinarity and would not harvest its fruits. In other words, the expectations and constraints associated to linking biophysical to social sciences in our projects pushed the field agronomists into a kind of rush ahead, under the pressure of agricultural economists. The latter were considering that the change in scale between field and farm levels imposed to greatly simplify the information relative to field level. They considered the pressure put on field agronomist as an effective way to ensure that the latter will accept these simplifications. The symmetrical situation may occur as well, i.e. agricultural economists endlessly refining their model whereas field agronomist plea for mercy, although it is less likely due to the relatively short validity period of models in social sciences as mentioned above.

MacMynowski (2007) proposed a process of “differentiation, clarification, and synthesis” in order to better deal with the relationship between power and knowledge that is at play in interdisciplinarity. This framework would greatly facilitate dealing with the kind of issues reported in the present subsection. One practical consequence of this approach would be that today, for studies such as those reported here, we would probably start from sharing conceptual (or very simply quantified) models and raw data at both field and farm scales, and jointly identify what aspect of the models should be refined (and in fact what we have done in case 2 in Vietnam was already close to that), instead of starting with preconceived ideas about what each of us had to do first. Note, however, that it is unsure whether we would have accepted such a raw merging of models, data and expert knowledge 15 years ago, because at that time we did not trust and respect each other enough to show right at the first meeting how few things we knew about the systems we pretended to study together.

3. CONCLUSION

Our 15 years experience of bioeconomic modelling suggests us some lessons about the issues relative to interdisciplinarity between biophysical and social sciences.

Naively ignoring the need for some teamwork devoted at building mutual respect and trust, and for patience in learning the culture and language of the other disciplines involved would probably the most effective way to prevent a multidisciplinary team from reaching its goal. Pretending to achieve interdisciplinary studies seamlessly, just thanks to the use of the right tools and human resources would most probably result in numerous scars at least in the memories of the participants ! But it is not so difficult for scientists to admit that interdisciplinarity, especially when cultures are as different as between social and biophysical sciences, will strongly exacerbate many of the small difficulties with which they routinely cope when interacting with others within the scope of their disciplines. Once this is acknowledged, guiding principles expected to reduce the impact of these issues are relatively easy to draw. Organizational patterns and management techniques can be adapted mostly on the basis that if it is more difficult, then more means and more time should be devoted the job (Marzano et al., 2006).

At the intersection of disciplines there are a lot of unclear or even unknown processes, the understanding of which being critical for interdisciplinarity to honour its promises. This requires innovative conceptual approaches that are more than the addition of the different conceptual framework of each discipline. The sooner the group identifies and address these processes the better. But two prerequisites are critical: trust and mutual respect have to be firmly acquired, and it must be recognized that there is some unavoidable share of subjectivity associated with the shift from purely biophysical systems to systems where human decision takes place. Otherwise, this unavoidable subjectivity may pave the way to the suspicion that a competition for some kind of power is at stake in the debate rather than the search for a better understanding of something.

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