Combining modeling approaches for participatory integrated assessment of scenarios for agricultural systems. An application to cereal production systems in Camargue, South of France.

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Keywords: Land use change, bio-economic model, agent-based model, organic farming, CAP, policies

Abstract

Models are common tools used for scenario assessment of agricultural systems. In this paper we present the combined application of three modeling approaches for participatory integrated assessment of scenarios for agriculture in the Camargue area (South of France). By means of a land use change analysis (LUC), an agent-based model (ABM), and a bio-economic model (BEM), we assessed with farmers and other stakeholders of the area scenarios related to the CAP reform and the possible extension of alternative, more environmentally friendly, farming systems. The LUC analysis was used as a tool to characterize, from a retrospective point of view, the capacity for change of farming systems. By identifying and measuring the main biophysical constraints and actual socio-economic situation, we were able to initiate the discussion with farmers and other stakeholders inside the Camargue region. The ABM has proved to be a powerful tool to organize and focus the collective discussions on possible adaptation strategies of farming systems. Finally the use of the BEM helped to discuss with stakeholders some plausible and desired scenarios for agricultural systems in the region. The combined application of the three modeling approaches is embedded in a more general framework for Prospective and Participatory Integrated Assessment of Agricultural Systems (PIAAS). In PIAAS, stakeholders play a central role in the definition of scenarios and indicators for their evaluation, the co-development of models, and their use for scenario assessment. Specific results for scenarios related to different subsidies levels for rice under the CAP reform and the reduction of pesticide use are presented as well as the evaluation of the whole framework by local stakeholders.

1) Introduction

Evaluating the impacts and performances of alternative cropping and farming systems at regional scales requires the use of proper systems analysis tools. Such tool contribute to the emergent discipline of integrated assessment of agricultural systems (IAAS, (van Ittersum *et al.*, 2008)). However, applying this evaluation in a prospective analysis of scenario for a specific rural aera is needed, as alternative systems may be adapted to the current context but may have serious drawbacks if the socio economic context change (Blazy et al., 2009). In our approach, a “scenario” follow the description proposed by Lopez Ridaura (2005): it is the combination of (i) technical alternatives that are potentially of interest, (ii) of objectives for agricultural systems translated into either local policy (e.g. agro-environmental measures to support specific practices) or threshold values of indicators of performance to be attained, and (iii) a change in an element of the biophysical or socioeconomic context of the system, such as prices and economic support to the agricultural production or climate change.

To assess such scenarios on a quantitative basis, models are essential tools as they can simulate the effects of change of context and of systems, and calculate multiple indicators for the different sustainability domains (economic, social and environmental) (van Ittersum et al., 2008). The widely accepted multifunctional nature of agriculture implies that the interests and objectives of the different stakeholders of a region concerning the evolution of farming systems have to be taken into account, in a participatory and multi-criteria approach (Voinov & Bousquet, 2010). Moreover, these interests and objectives are often attached to different spatial and temporal scales implying a multi-scale approach (Laborte *et al.*, 2007). On the basis of a comparative analysis of various modeling tools, we have developed the PIAAS approach (standing for Prospective and Participatory Integrated Assessment of Agricultural Systems; (Delmotte et al., 2012c). PIAAS combines detailed knowledge on cropping and farming systems with retrospective analysis of land use change, and the use of an agent-based model and of a bio-economic model to build and assess scenarios of agricultural evolution in interaction with the stakeholders in a given region. Although the different modeling approaches have shown different advantages and drawbacks for PIAAS, it remains a stake to develop a approach in which they would be used to get the most of each by combining them in a coherent manner.

This PIAAS approach that we developed is targeted to assist stakeholders in the negotiations of local policies as well as consensus building on local development objectives. Also, this approach had the expectation to contribute to identify with farmers the way they could adapt to expected or possible changes (such as change of policy or in the price of commodities) and attain given objectives (such as reduce the pesticide use by twice as it is expected at the national level).

This paper presents the PIAAS approach that was implemented in the Camargue Region (southern France. We first present briefly the case study and data, the models, and the participatory approach that were developed, and then the main results of their applications for two scenarios: foreseen changes in the Common Agricultural Policy 2013 and the reduction of pesticide use in the region.

2) Development of an approach for PIAAS in the Camargue

The Camargue is a deltaic region in the South of France of 167 000ha of which around 60 000 are used for agricultural production. Agriculture plays a crucial role in the economic, ecologic and social equilibrium of the region. It has been labeled as a reserve of biosphere (Man And Biosphere Program of UNESCO) since 1977, and it hosts also a Natural Regional Park, a National Reserve and many other associative or private protected areas. Several fauna and flora species are protected and eco-tourism is an important economic and cultural activity. Agriculture in the Camargue plays a crucial role in the water dynamics as most land is situated at sea level and salinization is a natural process due to the negative water balance between rainfall and evapo-transpiration in this windy Mediterranean climate. About 20 000 ha are devoted annually to rice production. It is the only place where rice is produced in continental France. Irrigation of rice plays a key role in desalinating the soils through fresh water pumped from the Rhone River into the delta. Figure 1 shows the perimeter of the Camargue region, as well as of the perimeters of the irrigation and drainage networks that regulate the inputs of water for rice irrigation, and the output of drainage water that allow harvesting and soil tillage during the rainy seasons, in autumn and spring. Rice cultivation has an important effect on the soils as it decreases the salt concentration via the drainage of the fresh water used for irrigation. It is grown in different cropping systems, varying from few successive years of rice (2 to 3 years in alternation with other crops) to rice mono-cropping. However, continuous rice production needs systematic use of pesticides, notably herbicides. These pesticides disperse throughout the environment and, given the high biodiversity of the region and interest of the local fauna and flora, ecologists have long called for a reduction in the use of pesticides.

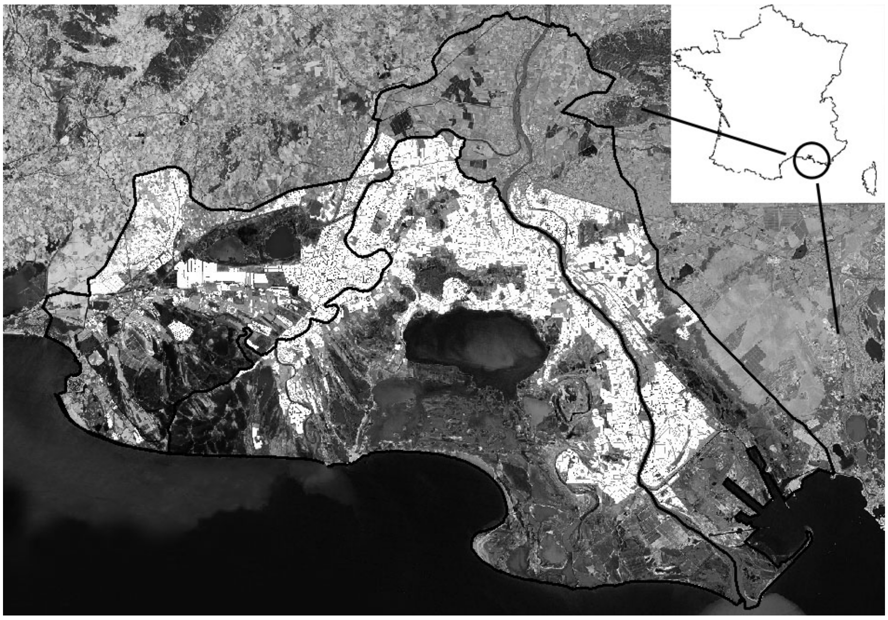

Figure 1. The Camargue Region. In black the limits of Biosphere Reserve. In white, all fields annually cultivated and considered in the study for scenario assessment. Data are missing for the north of the region but considered in the study (Data from the Natural Regional Park of Camargue and the Syndicat Mixte de la Camargue Gardoise)

Through 20 years of action research in the Rhone river delta of Camargue, a detailed knowledge of cropping and farming systems and their performances was acquired, as well as a solid network of farmers and local stakeholders (Lopez Ridaura *et al.*, 2010). We conducted a first series of 18 interviews with most influential stakeholders of the region (e.g. grain collectors, farmer syndicate and institutions in charge of rural development such as the natural regional park) to present the project and engage them in the process of defining scenarios and indicators for their evaluation. Their visions of the futures were discussed in term of perceived exogenous drivers of change and wished and unwished changes. Three main issues requiring the assessment of scenarios were identified at this phase of the project: (i) the impacts of the 2013 CAP reform and the expected suppression of the coupled payment for rice, (ii) the governmental objectives of decreasing by half the pesticide use and (iii) also a governmental objective of reaching 20% of agricultural area under organic farming (OF). The criteria they use to assess the current situation were discussed, as well as desired criteria to use for the assessment of scenarios related to the future. From these criteria, a list of 18 indicators at farm scale and of 10 at regional scale was latter proposed and agreed with them (see Delmotte, (2011) for details).

From interviews with farmers, farmers' field surveys (Delmotte et al., 2011), regional statistics, crop modeling and local expert knowledge, a database quantifying different technical coefficients (e.g. average yield for ten most common crops, labor demand, fuel, pesticides and fertilizers consumption) for the current and alternative agricultural activities (10 crops after 10 possible preceding crop under 4 different soil types and 3 orientations: organic, conventional or low input system) was developed (see Delmotte, 2011 for details). A farm typology was built using local databases and consultation of experts (see Delmotte and Goulevant, 2011 for details) in order to capture the variability of farming systems and their location in the territory but also to upscale the results of indicators from farm to regional level in the models. The resulting 9 farm-types depend on the size of farms, the proportion of rice in their cropping system and their farming orientation in terms of conventional or organic management : they are the (i) Specialized large size rice producer (farm area above 265ha, more than 80% of area cultivated on rice), ii) Specialized middle size rice producer (farm area below 265ha, more than 80% of rice, iii) Large size rice producer (farm area above 267ha, between 60% and 80% of rice) iv) Middle size rice producer (farm area below 267ha, between 60% and 80% of rice), v) Partially organic rice producer (Same land use as middle sire rice producer but an average of 20% of LU in organic), vi) Livestock breeder (Around 35% of rice, 35% of forages and 30% of other crops), vii) Organic livestock breeder (Same land use as livestock breeder but with partial or total area in organic), viii) Diversified crop producer (More than 50% of durum wheat and other crops, an average of 35% of rice), ix) Organic diversified crop producer (Same land use as diversified crop producer but with partial or total area in organic). A GIS was developed to get spatial information about soil types, altitude and irrigation infrastructure as well as the spatial distribution of farm types within the region. This information was necessary to quantify the different indicators to assess at multiple scales the scenarios with the different modeling tools, as reported in the next paragraphs.

3) Combining different modeling approaches for PIAAS for scenarios assessment with farmers and stakeholders

Three modeling approaches were used to develop and assess different scenarios related to the evolution of the cropping and farming systems in the Camargue. In this part, we report on the use of these modeling approaches by describing briefly the models and their use for scenarios assessment, the results obtained and the discussion that were held with the local stakeholders on the basis of these results.

a) Retrospective analysis of land use change

We gathered geo-referenced data sets in a GIS (MapInfo®) on (i) rice land use for eleven consecutive years (1998-2008) for the central sub-region (central island of Camargue) that was made available by one stakeholder of the region, the private research center of La Tour du Valat[1], (ii) the farm typology and (iii) a soil map edited by INRA[2]; to analyze the data at different scales: field, farm, farm-types and region. At all, 9130 fields are described in this database. We conducted a retrospective analysis of land use change (LUC), consisting in studying the past changes in land use and trying to link them to different hypothetical drivers that could explain the changes. We analyzed (i) the change over the eleven years in the proportion of rice production at the farm scale for each farm type and (ii) the frequency of rice for each field in relation to the soil type.

Figure 2-A shows the evolution of the proportion of surface devoted to rice production per soil type. At the sub-regional scale, it can be seen that rice production does not occur with the same frequency on the different type of soils. Fields with shallow (meaning that the salty ground water is close to the surface) soils are the most cultivated with rice, as between 45 and 55% of the area are cultivated on rice each year. About 37% of the alluvial hydromorphic fields were cultivated on rice in 1998, however it has increased up to nearly 48% in 2008, this level being close to the one of deep clay loamy soils (where the salty ground water is deeper). It can be seen that the deep loamy clay soils have in 2008 a slightly lower frequency of rice than shallow clay loamy soils and salty and hydromorphic soils, while deep sandy soils are always managed with lower rice frequency.

Figure 2 B shows the evolution of the average proportion of farm area devoted to rice, for nine farm types. While the organic livestock breeders had a stable 20% of their area in rice, the conventional livestock breeders and the diversified crop producers had a downslope trend. Specialized rice producers had a stable or increasing rice area.

These results were used to initiate first discussions with stakeholders. Taking into account the current CAP high subsidy level for rice production, this analysis shows the vulnerability of specialized farmers to CAP reforms. Although local examples of low input systems and OF systems show little rice proportion in the farm area, implying that for pesticide reduction and OF development, the farm types with a high rice proportion will have to deeply change their systems. These two objectives cannot be achieved without a shift to long and diversified rotations and therefore a reduction of the rice area on lands. Livestock breeders and diversified cereal producers can in this logic be expected to be more resilient to the foreseen reduction of rice coupled payment, and could more easily convert to organic production. These hypotheses, formulated on the basis of these results and from the empirical knowledge of the stakeholders, had to be assessed further with farmers, implying the need for participative workshops for scenarios assessment with farmers.

[1] http://www.tourduvalat.org/
[2] http://www.gissol.fr/programme/bdgsf/bdgsf.php

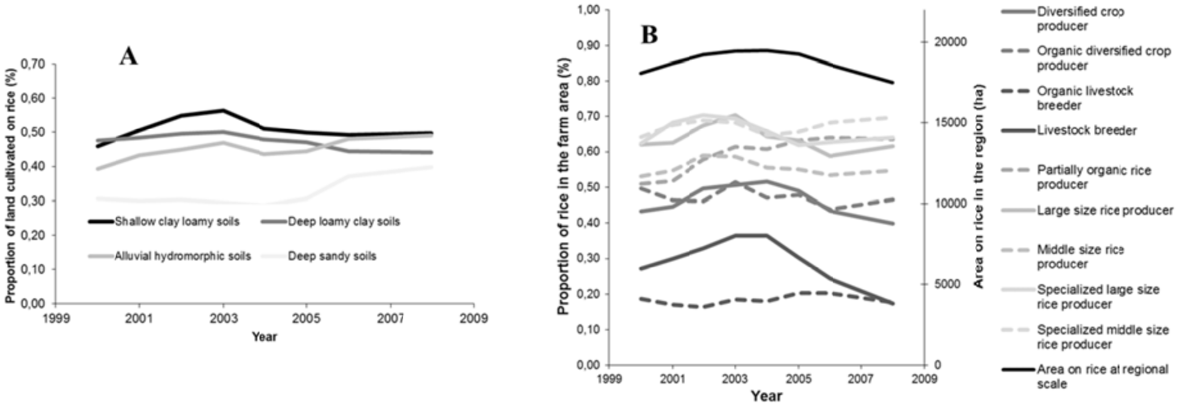

Figure 2. A. Three year moving average of the proportion of rice area per soil type at the regional scale. B. Three years moving average of the proportion of rice fields for the 9 types of farm.

b) Assessing a CAP reform scenarios using an ABM with farmers

We then developed an interactive agent-based model (ABM) where farmers take decisions and formulate choices for a hypothetical farm similar to theirs (derived from the typology). Each farm is described by ten fields on which farmers must decide for each time step (a year) of the simulation the crop and orientation of production. The model calculates for each time step 17 indicators at farm scale, that the farmer can use to assess its choices. Participative workshops were conducted using the ABM with 14 farmers to explore a scenario related to CAP reform (see Delmotte et al., (2012b) for more details). Simulations were done for seven consecutive years where the specific subsidy for rice was not given from the year 3 onward. Results of the indicators previously identified at different scales (e.g. field, farm, water distribution area) with the farmers (e.g. gross margin, labor demand) and other stakeholders (e.g. employment, water use, subsidies) were analyzed and discussed after each time step.

Figure 3 A presents the evolution of the gross margin as simulated by two farmers. The specific subsidy for rice was not distributed from the year 3 onward. Both farmers reacted to the hypothetical CAP reform by converting part of their farm to OF. The CAP reform and consequent conversion to OF didn't have a large effect for the livestock breeder while for the rice producer conversion to OF implies a diversification of production, and an initial decrease of gross margin due to the reduction of rice surface in the conversion to OF. At the end of the simulation, gross margin of the rice producer is recovered as, once the transition period has ended, all productions are sold at the prices of organic products. Figure 3 B shows the evolution of four indicators at regional level obtained from the aggregation of the strategies chosen and virtually applied by the 14 participants (diversification, input reduction and conversion to OF) using the spatially explicit typology. The aggregated total value of regional production decreased from 45M€ to 36M€, with a slight increase at 39M€ at the end of the simulation. The pesticide used, assessed with the treatment frequency index (TFI, sum of pesticide application at a full dose on the whole surface of the field) at regional level, decreased by 28% (from 2.5 to 1.8) due to the reduction of rice production in the region (the area is reduced by half) and to the conversion to OF (increased by 50%).

These results were discussed during different occasions: first, during the interactive simulation sessions, the strategies adopted by the farmers and the results of the scenario at farm and regional level were discussed collectively. Secondly, the different strategies and the aggregated results were presented to the main stakeholders of the region during individual meetings. The stakeholders reacted to these results by formulating new questions. For example, the French Union of Rice Producer and Industry (FURPI), that was at that time negotiating a new coupled payment with the ministry of agriculture, wanted to know the minimum level of coupled payment that would ensure the same area under rice cultivation in the region, as they found this necessary to maintain a productive supply-chain and the soil quality through its regular desalination by fresh water. Another example is the Natural Regional Park of Camargue (NRPC) which, acknowledging the fact that the disappearance of the rice coupled payment may decrease the use of pesticide (although below the objective of a 50%), had questions related to the possibility and cost of reducing the pesticide use to this level. To give elements of answers to these stakeholders, we then developed a bio-economic model.

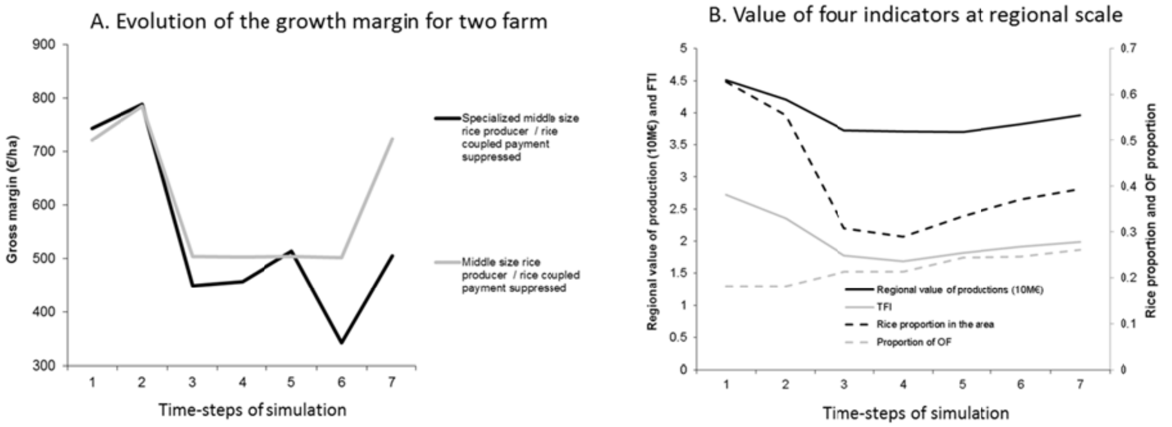

Figure 3: A. Evolution of the gross margin of two farms during the 7 years of simulation. B. Evolution of four indicators calculated at regional level.

c) Pursuing the assessment of the CAP reform and extending the range of scenario using a BEM

A multi-scale Bio-economic models (BEM) was developed with the stakeholders to build and assess a great number of scenarios related to the questions formulated after the presentation of the results of the ABM. To ensure that they had a clear understanding of the functioning and the underlying hypothesis of the bio-economic model, it was developed through a participatory framework in four phases, consisting in (1) presenting the model principles, (2) developing the scenarios, (3) assessing the scenarios and (4) assessing the modeling exercise. This framework is detailed in Delmotte et al., (2012a).

Figure 4 A presents a radar graph at regional scale, when all farms had a minimum of 20% of the lands converted to OF. The objective was to maximize the gross margin of all farms with different constraints of reduction of the pesticide use index (TFI) with conventional and organic activities. In all farm types, when 20% of land area in OF was possible, the organic activities were immediately adopted due to the relative economic attractiveness of organic systems compared to the conventional ones. Reducing the TFI from the current value of 2.1 to 1.2 at regional scale would have impacts on the agricultural sector in the region (Figure 4 A): the regional value of production would be decreased by almost 15% while the rice area would be decreased by 37%. These changes in cropping systems may also imply a reduction of employments generated by the farming activities as the total labor time would be decreased by 14%. It could plausibly also have positive impacts for the environment as, in parallel to the pesticides reductions, the fuel used for all mechanical activities would be reduced at regional scale by 11%. The amount of subsidies at regional scale would not change much in this scenario, where no coupled payment for rice has been taken into account. Setting the constraints of reduction of the TFI at farm or regional scales gave different results. Reducing TFI at regional scale had a greatest influence on farm types that produced rice in a higher proportion, due to the high TFI of this crop. The TFI reduction for these types of farms was more pronounced because it was less costly for the region to reduce primarily in this type of farm than in farm that had already low TFI. However, when the regional TFI was 1.9, reducing it to 1.8 implied to modify also the TFI of livestock breeding farm (Figure 4 B). This compensatory effect between farm types reflected the inequality of cost of reducing the TFI between farm types for reducing the regional TFI.

The discussions of the results of the different scenarios and specific interviews with the local stakeholders were used to evaluate this approach. In the case of the FURPI for example, the results of the scenarios assessed were found difficult to be handled for negotiation with the French ministry of agriculture due to the high variability of the results obtained when the scenarios make use of different prices of commodities, although these prices reflected the variability observed in the last five years. On the contrary, for the NRPC, the results were found interesting as they showed that it was possible to decrease the pesticide use and that the effort should be concentrated on specific farm types, notably the ones that currently use grow mainly rice and use the highest quantity of pesticide.

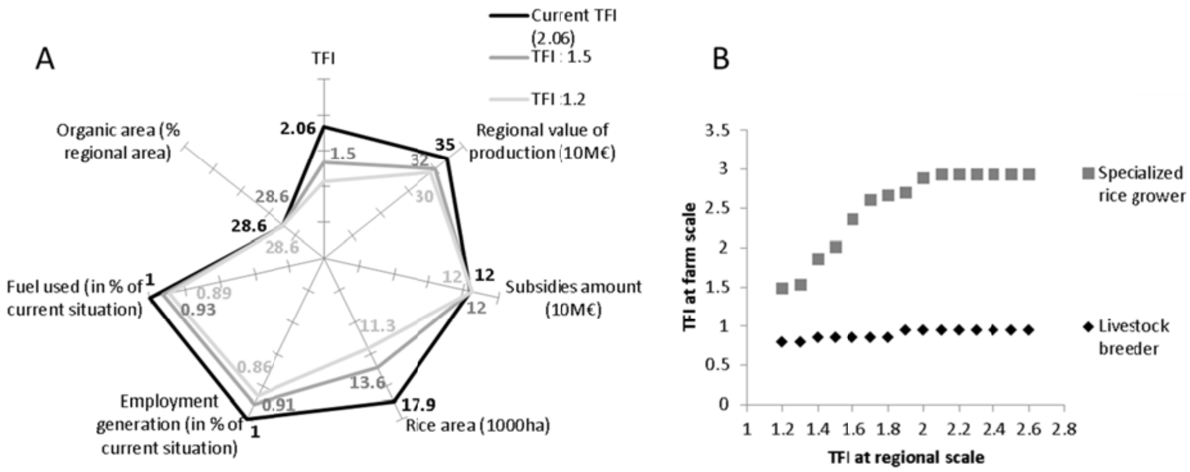

Figure 4: (A) Spider diagram of three scenarios at regional scale of TFI: the current TFI level, a regional TFI of 1.5 and a TFI of 1.2. (B) Trade off curves between the TFI of two farm types and the regional TFI.

4) Discussion: combining three modeling approaches for scenarios assessment with stakeholders

Combining the three approaches for the evaluation of scenarios highlights their complementarities. Even if we had originally planned to use the three of them in the PIAAS approach, the way they would be articulated in a coherent development of the case study analyses was decided step by step, as a reaction to stakeholders need for scenario assessment.

The LUC analysis was used as a tool to make hypotheses, from a retrospective point of view, on the potential adaptability to the CAP reforms and on the potential of conversion to OF by different farm types. However, while this approach could be used for prospective analysis through scenario development, we found that the scale it was applied here was too small as it was not possible to identify spatial drivers of change that would differ in different sub-regions of the territory.

The ABM was used to test possible adaptation strategies of farmers and to organize and focus collective discussions among farmers, and to serve as a basis to enhance discussions with the stakeholders, notably on the futures they could imagine for the farming systems and on their own objectives regarding them. The use of the model with farmers allowed checking, modifying and validating the multiple data used to quantify the indicators. This was found essential to ensure the credibility of the results simulated with the ABM and with the BEM, as the other stakeholders felt confident in the figures used and validated by the farmers. Nevertheless, this approach is too time-consuming to be applied for multiple scenarios assessment, due to the difficulty to multiply the interactive simulation sessions with farmers (it takes half a day to assess one scenario). From this point of view, the BEM is complementary as it allows assessing a great number of scenarios with the local stakeholders in a minimum time requirement, once the model has been developed on a participatory manner. The BEM can therefore be used for assisting reflection on plausible and desired scenarios for the future; however it may remain difficult to communicate with farmers and discuss the results if they did not participate in the model co-construction. It seems therefore necessary to use alternatively the two kinds of model to work with both farmers and local stakeholders.

The assessment of the global approach by the farmers and local stakeholders helped identifying issues for further development. The farmers found the approach powerful to help them thinking of possible adaptation they could do on their farm, while the other stakeholders appreciated the transparency of the tools as an advantage for negotiation among them. Uncertainty and validation of data and models was a recurrent subject of discussion during the evaluation of the approach, and the capacity to change the value of certain parameters during interactive simulations was found necessary to enhance confidence in the simulation. Some stakeholders claimed for collective sessions for the assessment and discussions of scenarios that could be organized with both farmers and institutions in charge of crop production and of environmental protection. These sessions would have the objective of identifying and discussing possible trade-offs between crop production and environmental protection. This could be done in a final workshop using the ABM, to delimit the solution space for different scenarios and guide farmers choices as well as the development of local environmental policy measures. This workshop is being organized and its results may be presented during the congress. This work has also served as the basis for the development of a new project aiming at identifying with farmers low input systems that could be developed in Camargue, and eventually accompanied by local agro-environmental measures that would be set by the NRPC.

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