Regional conversion to Organic Farming in Camargue, south France. A multi-scale integrated assessment of scenarios.

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ABSTRACT

The rapid growth of organic agriculture in the last decade suggests that this form of farming might become more common and its extension may cover large parts of certain regions. The regional conversion to Organic Farming (OF) might represent great advantages in terms of ecosystems integrity and local natural resources conservation.

However, is this regional conversion plausible? What could be the impact of such conversion for agricultural production and nature conservation? Taking into account the heterogeneity of farms and farming systems in a region, are there farming systems more easily convertible than others?

The objective of this paper is to show the results of different scenario analyses about the extension of OF in Camargue, South of France. The application of different modeling approaches with great potential for the multi-scale and multi-criteria evaluation scenarios is presented. These models include Bio-economic models, Agent-based models and Land use/cover change models.

According to our results, in the Camargue, the most probable conversion in the near future would take place in fields with low salt pressure belonging to livestock breeders and diversified cereal producers. However, the regional conversion to OF is plausible as the region could maintain its economic productivity while decreasing the potential harmful effect to the environment. Finally, the possible trajectories of conversion suggest that certain farmers (specialized in rice production) might need greater help to assure such conversion to OF as their economic performance is hampered during that period.

The application of these three modeling approaches to assess the same scenario in one region revealed their complementarity for exploring the issue of regional conversion to OF from different angles and at different scales.

1. INTRODUCTION

1.1 Regional conversion to OF, new challenges.

Organic Farming (OF) has reached the status of a viable option for more sustainable agriculture among farmers, policy maker and consumers. In 2009, it was practiced in over 3.5 million hectares in the EU25 representing 5.1% of the agricultural area. In some countries like Austria, Switzerland, Sweden, Estonia and the Check Republic, organic farming occupied more than 10 % of the agricultural area in 2009 and in other countries like Spain, Greece and Portugal the surface on organic agriculture has tripled in the last ten years (EUROSTAT, 2009).

This rapid growth of OF suggests new horizons for the future evolution of agriculture in general and of organic agriculture in particular. At the farm scale, the conventionalization of OF has been widely discussed by Darnhofer et al (2009) witnessing, on the one hand, an increase on the size of organic farms and their specialization and, on the other, higher intensification of the agricultural techniques (e.g. more concentrate use and disease treatments for animals and an intensive use of organic fertilizers in arable land).

The effects of this extension of OF set new challenges for agricultural research where new questions are rising related to the effect of total or partial conversion to OF of a given region (Acs et al., 2007).

For example, is the regional conversion to OF possible? What could be its consequences at regional scale in terms of social and economic development as well as nature conservation? Taking into account the heterogeneity of farms and farming systems in a region, are there farmers more prone to conversion and others facing greater obstacles?

To answer such questions, a prospective analysis has been carried out to assess different future scenarios on the extension of OF. Such assessment has to be able to take into account the different objectives (e.g. economic, environmental, social) of stakeholders related to agriculture in a given region, by means of indicators relevant to the scales at which they operate (e.g. field, farm, watershed, region).

1.2 The Camargue region case study

The assessment of the consequences of the extension of OF at the regional level was done for the Camargue region in the South of France. In Camargue, a deltaic region in the south of France, OF has been presented as a potential way for reducing the externalities of current agricultural practices. There, agriculture plays a crucial role in the economic, ecological and social equilibrium of the region. The region has been labeled as a Biosphere Reserve (Man and Biosphere Program of UNESCO) since 1977, and hosts a Natural Regional Park, a National Reserve and many other associative or private protected areas.

About 50 000 ha are cultivated in Camargue. Farming systems are based on the production of cereals and livestock breeding. The main crops of the region are rice, durum-wheat and in lower quantity sunflower, maize, oil seed rape and sorghum. Irrigated rice is the main important cropping activity with about 20 000 ha devoted to it each year. Irrigated rice can take place in the four main soil types of the region: deep soils are sandy or loamy-clay soils, sandy soils being less favorable for rice cultivation due to difficulty to maintain water in highly draining soils. Shallow soils are clay loamy or salty and hydromorphic soils. Both require a quite high frequency of rice cultivation (one year over 3 at minimum in salty and hydromorphic soils, to desalinate and allow the production of rainfed crops).

Cropping systems play a crucial role in the water dynamics of this deltaic region. Most land is at sea level and salinization is a natural process due to the negative water balance between rain and evapotranspiration. Irrigation of rice plays then a role in desalinating the soils. Irrigation water that enters through pumping from the Rhone-River plays also a key function to maintain the level of water and salt concentration of the central lagoon of the Camargue, the Vaccarès (Figure 1) that is the temporary habitat of several migrating bird species.

However, conventional rice production uses large quantities of pesticides, mainly herbicides. These herbicides disperse throughout the environment and, given the high diversity and interest of the local fauna and flora, ecologists have long called for a reduction in the use of pesticides. The extension of OF in the Camargue would certainly imply a decrease in the area of irrigated rice due to the difficulty of managing weeds in these systems. In fact, one crop of organic rice on a single field has to be separated by at least five other crops (i.e. by five years), whereas in conventional cropping systems, it is possible to grow continuous rice by using herbicides (Mouret *et al.*, 2004).

2. METHODOLOGY

2.1 Three approaches for scenario assessment

In relation to agricultural systems and land use we identified three approaches commonly used for scenario analysis (Delmotte et al., Submitted): (i) Land use change modeling (LUC), (ii) Bio-economic modeling (BEM) and (iii) Agent based modeling (ABM). These three approaches are briefly described in the next paragraphs.

The objective of LUC models is to describe the actual land use and to give insights on the possible changes of land use pattern that would occur in the near future following either some biophysical or demographic changes (Veldkamp and Fresco, 1996) or economic and structural changes (Verburg et al., 2004). LUC approaches cover a wide range of methods but most of them are “descriptive models that aim at simulating the functioning of the land use system and the spatially explicit simulation of near future land use patterns” (Verburg et al., 2004).

In Camargue, a land use and land use change analysis was conducted using a geo-referenced data set on the soil occupation for eleven years (1998-2009) and observing (i) the change in the proportion of rice production at the farm scale for each farm type and (ii) the frequency of rice over the eleven years for each field in relation to the soil type. The land use data were crossed in a GIS with the spatially explicit farm typology to get data at different scales: field, farm, farm-types and region. At all, 9130 fields are described in this data base.

Bio-Economic Models (BEM) aim at identifying optimum allocation of agricultural activities (e.g. cropping, livestock), in space and time, which maximize or minimize an objective (see Jansen and van Ittersum (2007) for a review on BEM). In integrated assessment, including several criteria and indicators, optimum systems are obtained using a Multiple Goal Linear Programming model (MGLP) (van Keulen, 1990)). In MGLP, one criteria is defined as the objective function, the other criteria being set as constraints. This optimization has been done for objectives defined at different scales, most commonly at the farm (Janssen and van Ittersum, 2007) and regional scale (Laborte et al., 2007).

In Camargue, two BEM models were developed, one at the farm scale and another one at the regional scale. In both models all indicators can be either maximized or minimized depending on the objectives of stakeholders at different scales. Also, indicators can serve as constraints for the optimization.12 indicators representing the economic, social and environmental criteria related to agricultural issues were included in the models. These indicators included, at the farm scale, the gross margin, labor needed, production costs and pesticide use among others. At the regional level, indicators included the value of agricultural production, the employment generated, the level of subsidies, water and pesticide use, among others.

Agent Based Models (ABM) represents systems as agents in interaction, with a social structure, and using resources in an environment. Agents perceive, self-represent and act in their environment by making decision and interacting with other agents. Each agent has its own tendencies and objectives (Ferber, 2006). ABM is an approach originally developed from computer sciences to study the dynamics of complex systems and reproduce phenomenon that emerge from the addition and interactions of individual behaviors. ABM can be based on multiple formalisms for representing the decision-making by the agents. In case of human agents, decision-rules are often defined with thresholds and if-then rules (conditional).

For the Camargue analysis, a ABM was developed under the Cormas® plateform (Bousquet et al., 1998) for interactive simulation with farmers and results shown here were obtained during test applications carried out with university students in agronomy. The ABM is based on individual interfaces for each farm type and each participant represented a farmer of a defined farm type having specific resources in terms of farm size, soil type distribution and initial condition of cropping system.

Each participant decided which agricultural activity to allocate in each field, its decision concerned the choice of crops, style of production (conventional or organic) and the level of inputs for each field. Each participant had also to consider the total area of each crop on a given year at the farm scale and the preceding/following crop couple at the field scale in order to keep coherent rotations. The interactive simulation was conducted for 7 time steps, a time step corresponding to a year. Students had the objective to convert partially and totally their farm to OF while maintaining as much as possible their gross margin and the labor demand at the farm scale. During the 2 year conversion period to organic farming input and outputs for organic activities were used while conventional prices of production were used.

2.2 Quantifying cropping activities and describing farm types in Camargue

For the evaluation of scenarios, a large range of cropping activities were defined and quantitatively described. The definition of the agricultural activities follow the concepts developed by Hengsdijk et al., (1999) and corresponds to the combination of a crop, established in a soil type, with a preceding crop, a distinct management system and a given level of input use.

Due to the too few references concerning OF systems in the region, only one intensity level was described for organic crops. At all, we obtained 1200 possible agricultural activities. Each activity was described quantitatively by the calculation of different technical coefficient, such as the labor demand, inputs used or the cost of production. Inputs for the different activities (fertilizers, pesticides, seeds, machinery) were calculated based on several technical reports from the region, more than 20 reports of student interviewing farmers and a series of interviews to key farmers to complete the data (LeQuere, 2010). Labor demand was quantified from a detailed database built on the basis of these data that described precisely each cropping system with tractor and machinery use and the time needed for each operation as well as the period or realization. Yield for rice was estimated based on a database analysis containing more than 350 fields surveyed in different years (Delmotte et al., 2011). Yield for other crops was estimated together with experts from local technical institutions and from average yields reported for the region by the grain millers. For the calculation of economic indicators, average prices of inputs declared by inputs suppliers and crop prices declared by the cooperative from 2009 and 2010 were used. The subsidies details and amount were averaged from farmers' interviews.

For up-scaling the assessment from farm to regional level, a spatial farm typology (with perimeters of each farm represented in a GIS) was built using several data base (Delmotte et al., 2011). The resulting 9 farm-types depend on the size of farms, the proportion of rice in their cropping system and their farming style 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).

3. RESULTS

3.1 Probable spots for conversion to OF in Camargue using a land use change model

Figure 1-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 soils. Fields with shallow soils are the most cultivated lands in 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 shallow clay loamy soils. 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.

Farmers therefore seem to have a different management strategy for shallow and deep soils, rice being preferably allocated to shallow soils, most likely due to salt issues. To convert to OF, fields with shallow clay loamy soils and salty and hydromorphic soils would certainly have more difficulties and consequently, farmers with a high proportion of these types of soils, will also face problems converting to OF.

Figure 1-B shows the evolution of the percentage of fields cultivated on rice for the 9 farm-types described in table 1. First of all, it has to be noticed that the typology, which was done on an independent data set, is validated by this figure: livestock breeders have lower rice proportion in the farm area than diversified crop producer (either organic or conventional) and than rice producers or specialized rice producers. Both systems totally in organic (livestock breeders and diversified crop producers) have a stable rate proportion of rice, that is always lower than 0.5. However, partially organic rice producers have a proportion of rice that is not different than the proportion of non-organic rice producers. This corresponds to the partial conversion (e.g. 20%) of the farm area into organic.

Conversion to OF therefore seems to be possible in two ways: attaining a lower rice proportion in land use, the situation of diversified crop producer, or converting only a part of the farm to OF as shown by the partially organic rice growers that keep high proportion of the farm into conventional management.

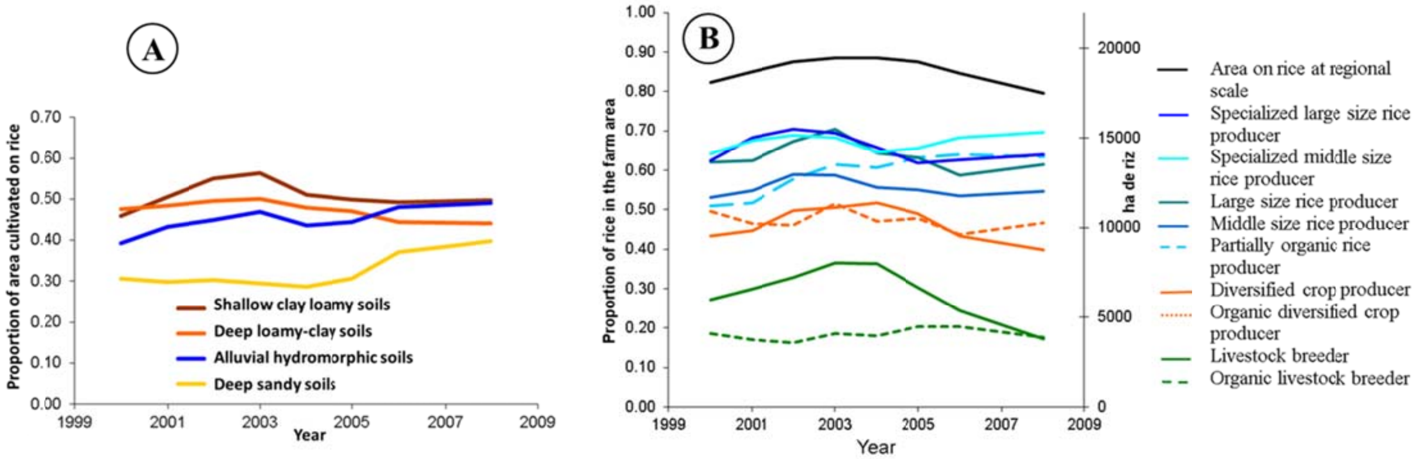

Figure 1: A. Three year moving average of the proportion of rice fields per soil type at the regional scale. B. Three years moving average of the proportion of rice fields for the 9 types of farm.

3.2 Plausible consequences of the conversion to OF in Camargue using a Bio-economic model

Figure 2–A presents a radar graph with 6 important indicators for a 'specialized rice producer' farm when the gross margin is maximized with conventional and organic activities, as well as under the current situation. Being the outer circle of the radar the best values for each indicator, it can be seen that organic and conventional activities provide similar value of gross margin, costs, subsidies and labor. Water used in the current situation is similar to that under organic production (in both cases less water used than in the conventional optimization) but in terms of pesticide use, it can be seen that reduction of pesticides used can be achieved without scarifying much gross margin or even improving it at the same time.

Compared to the current situation, it can be seen that gross margin can be nearly doubled with both conventional and organic production forms however, it has to be taken into account that the MGLP is optimizing a single year and most land is under irrigated rice and rainfed cereal production (sorghum or maize or wheat) with an important proportion under rice while in the current situation other crops are inserted in the rotations. In other words, to reach such level of productivity in both the organic and conventional scenarios, in previous and/or following years a decrease in productivity can be expected.

In figure 2-B two contrasted scenarios are maximizing the value of agricultural production at regional scale with either conventional or organic production. While the conventional scenario shows marginally better values of agricultural production and employment, the optimization with organic activities uses less than half the water used with conventional activities and a decrease in the subsidies needed to support agricultural activities. In the conventional scenarios, rice is chosen as the main crop (67%)

which implies high mechanization level of agriculture and a consequent increase in labor demand (employment) and higher fuel consumption.

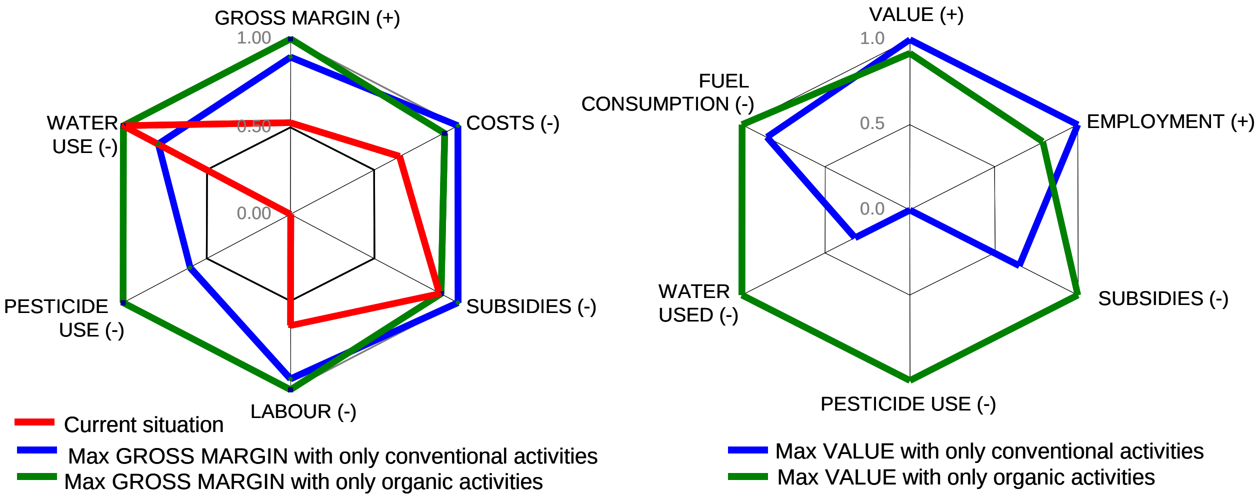

Figure 2. A: Current situation for a middle size specialized rice producer and under scenarios of maximization of gross margin with conventional and organic activities scenarios. B. Scenarios of maximizing value of production in Camargue with organic and conventional activities

3.3 Possible trajectories of conversion to OF in Camargue using a multi-agent model

Figure 3-A the evolution of gross margin is shown for two different farm-types, a middle size rice producer and a livestock breeder. It can be seen that for the livestock breeder there is little effect of conversion to OF, the gross margin being quite stable along the simulation. For the specialized large size rice producer, it implied the diversification of production and therefore a reduction in the surface devoted to rice. At the end of the simulation, this type of farm will possibly reach higher gross margin value as, once the transition period has ended the prices of organic products and subsidies for maintaining OF are used for the calculation of gross margin.

Figure 3 B, the evolution of the gross margin of the rice producer is presented as well as the evolution of water use. OF can help to maintain satisfying gross margin while reducing the water use. Applying this ABM allowed to identify that different farming structures have different capabilities to convert to OF. The conversion of the specialized large size rice producer implies in the first year of conversion a reduction of the gross margin, even if the conversion is supported by a subsidies of 150€ per hectare as it was the case in the simulation. The livestock breeder, with a margin being less dependent on rice and having more crop diversity in the farm is less impacted

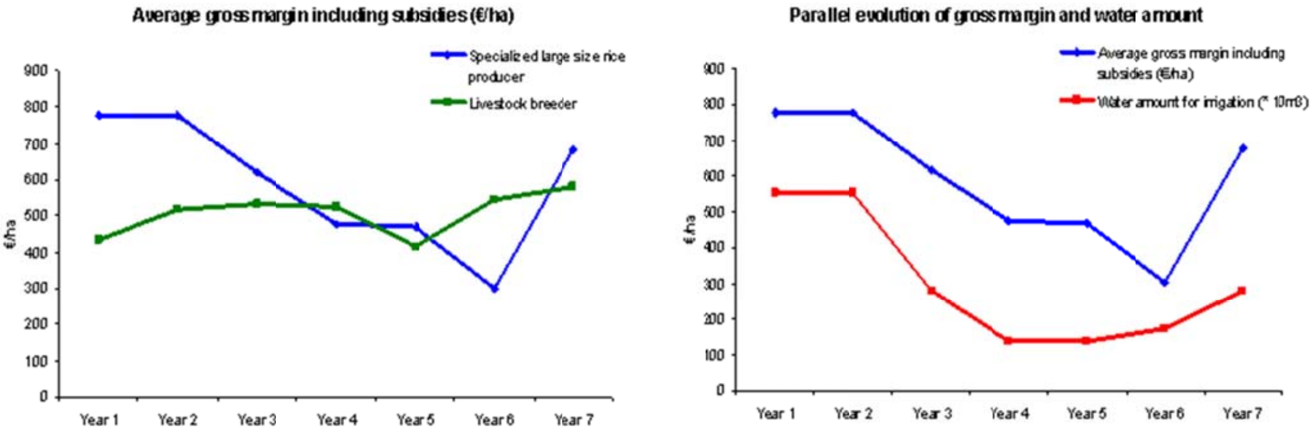

Figure 3. A. Simulation of the evolution of gross margin for two different farm-types and the proportion of land under OF. B. Evolution of gross margin and water use for irrigation in a middle size rice producer.

4. DISCUSION AND CONCLUSIONS

In this study we have showed three approaches that contribute to shed light on these questions. The three approaches were applied to the extension of OF in the Camargue region, South of France. These approaches answer to different and complementary interrogations related to the regional conversion to organic farming.

The LUC model, allowed us to identify the most probable spots for conversion in Camargue. By analyzing the past trends of farming systems in Camargue, livestock breeders with high proportion of shallow clay loamy soils and salty and hydromorphic soils (mainly under pasture) and diversified cereal producers are the farm-types more prone to switching to organic cropping systems due to suitable combination of soil types and farming orientation to lengthen the rice rotation. Specialized and non-specialized rice producers might restrict themselves to a partial conversion to OF in specific fields with suitable soil types.

The main trend of conversion in the near future will, most likely, take place in deep soil of farms with low proportion of rice in their cropping systems. However this expected change only concerns 20% of the arable land of Camargue. Other farmers such as the specialized rice producers and rice producers with a fair proportion of shallow clay loamy soils and salty and hydromorphic soils, and representing 45% of the arable land of the region, would see conversion as a much more difficult task. Or at least, it seems improbable to see a spontaneous (versus assisted) conversion to OF in the near future.

The BEM model allowed us to explore options in what could be called plausible futures (van Ittersum et al., 1998). It also allowed us to calculate several indicators for multicriteria analysis of scenarios revealing some of the trade-offs among indicators if total conversion to OF. The total conversion of the region to OF is plausible. With current prices, the region would not lose in terms of economic productivity by converting to OF and at the same time, it would protect the environment from the potential harmful effects of pesticides (Comoretto et al., 2007; Höhener et al., 2010). However the required extensification of cropping systems (i.e. less rice in the rotation) will plausibly have negative effects on the employment generation in the sector. Also the volume of fresh water that it is pumped into the delta might decrease with possible effects on the level and salinity of the central lake and on the conservation of the wild habitat of fresh water species.

With the BEM, trade off curves can be quantitatively described by maximizing one indicator while setting another one as constraint and progressively relaxing it (Lu and Van Ittersum, 2004; Lopez

Ridaura, 2005). Such curve might help to better understand the trade-off between productivity and volume of water used in relation to the regional conversion of Camargue to OF and identify an optimal solution where both objectives are simultaneously satisfied. However, non-linearities related to the spatial distribution of fields under irrigated rice in the region and their interaction, which governs the volume of water that actually enters the lake, might not be captured by this approach and other types of modeling would be needed such as agent-based modeling.

The ABM model presented here was developed for interactive simulation to elucidate the possible trajectories towards conversion to OF. In the participative exercise presented here, it can be seen that the transition to OF by farms specialized in rice production is much harder than for other types of farms, confirming what was seen in the LUC model. However, following the trajectory of conversion, it can be seen that after several years, the profit of this kind of farmers can almost be recovered (confirming the results of the BEM at the farm scale). These results suggest that conversion to OF for these types of farms may not come spontaneously and greater support might be needed, at least during the conversion phase.

The application of the three approaches provided the following learning: the regional conversion to OF in Camargue is plausible, the most probable spots for change in the near future are fields with enough drainage to avoid salinization problems from livestock breeders and diversified cereal producers and, finally, the possible trajectories of conversion suggest that certain farmers (specialised in rice production) might need greater help to assure such conversion to OF as their economic performance is hampered during that period.

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