Elaboration of coexistence scenarios from fields to primary grain collection

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Abstract

Role-playing games were organised to see how farmers, grain merchants and technical advisers would manage coexistence in the cases of oilseed rape in Beauce (France) and maize in Alsace (France). Access to information and coordination ability were identified as major factors affecting the feasability of coexistence. Four scenarios depending on stakeholders' management ability and structural admixture risks were built. These results raise the issue of the coupling between the rigidity of regulation and the diversity of the strategies used by the stakeholders to manage grain quality.

1. Introduction

According to EC regulations 1829/2003 and 1830/2003, each Member State of the European Union should determine the appropriate means to ensure a separation of GM and conventional food supply chain, so that the GM presence in conventional products stays below the threshold of 0.9%. In some cases, the objective may be lower, for example in the corn starch industry, where grain merchants have opted for a 0.1% threshold.

There are several sources of admixture between GM and conventional supply chain: "gene flow" through cross-pollination between fields, seed persistence in the soil in the case of oilseed rape (OSR), but also admixtures at harvest (combine, trucks) and further downstream (silo, drying, etc.). Factors affecting gene flow are diverse, and have been extensively studied during the past decade, as shown by the synthesis produced by the SIGMEA[1] project (Messéan et al., 2009). Beyond these purely technical aspects how stakeholders make decisions should also be taken into account. Although a professional know how exists for the management of grain quality (for example high erucic acid rapeseed (HEAR), waxy maize, seed production...), this question has been less studied. In consequence, a dual set of "structural" and "organisational" constraints have to be considered when studying coexistence.

The strategy proposed so far by the governments to ensure coexistence is based on standards binding actors' practices, such as isolation distances between GM and non-GM crops. This strategy may be criticised for several reasons. The efficiency of these standards is controversial, as is their practical feasibility. The debate is open to know if these standards should be universal or contextually adapted. Indeed, studies from various disciplines have shown the benefits of so-called "flexible" measures, i.e. adapted to local conditions rather than "rigid", i.e. universal and designed to remediate a "worst case " (Devos et al., 2008).

The practical implementation of coexistence involves taking requirements from different stakeholders into account. For example, the law maker wishes to better understand the conditions for the implementation of coexistence, in order to improve the quality of laws and regulations. On the other hand, professionals ask for tools and services to comply with the market requirements.

What could be coexistence in practice? As part of the European Project SIGMEA, we sought to produce management scenarios in some case studies, to finally produce a comprehensive model for structuring the discussion of the different stakeholders. The study focused on the case of Bt corn and herbicide tolerant OSR in well differentiated European regions, and was confined to the segment between the cultivated field and the primary collection silo, i.e. the first level of the supply chain after harvest.

Starting from the assumption of a dual set of constraints, both structural and organisational, we built up a two-step methodology. As gene flow operates over large landscapes, and in the case of OSR, on the long term, we first sought to quantify this using simulators operating on these space and time scales. We showed that risk at the field or silo level varied between regions but also within each region. We were able to stratify situations depending on the region, the ratio GM / conventional area, and the required threshold (Le Bail et al., Submitted; Sausse et al., 2007).

In a second step, we identified organisational factors specific to stakeholders' points of view and expertise through role-playing games supported by the gene flow simulators used in the previous step. This allowed us to propose management scenarios. This article details the work done in this second phase.

2. Material and methods

The approach involved a method based on the concept of policy exercise (van Asselt and Rijkens-Klomp, 2002). By combining role-playing game and modelling, as proposed by Barreteau et al. (2007), we were able to place the participants in a situation in which they were required to manage coexistence (role-playing), and we were able to represent the consequences of their decisions (modelling).

2.1. Design of the role-playing games

The design of the role-playing games was based on a previous analysis of the grain quality management from field to primary grain collection, and on the identification of subsequent critical points (SIGMEA deliverable 7.3[2]). According to this study, we chose to consider the risks of cross-pollination between GM and non-GM fields, the risks of mixing in predrying cells, and the risks of mixing in combine harvesters which were considered more critical than the risks of mixing in trucks and dryers (with respectively low GM presence and more possibilities of cleaning). The key roles were identifed thanks to this previous study: farmers, grain merchants, contractors for harvest, and technical advisors.

These games took place on maps describing landscapes of a few hundred hectares. We worked on two cases: OSR in Beauce and maize in Alsace. The games took only the spatial aspects of coexistence into account, but not the temporal management of OSR volunteers in the crop rotation.

Each participant played his own role. This choice aimed at maximising their diversities: farmers having various farming systems, cooperative or private companies for the grain merchants. Most participants had already been invited to a meeting about coexistence a year earlier. Resources were allocated for each role as shown by Table 1. The GM market was considered less profitable than the other non-GM markets. A member of the research team played the role of a farmer, hereafter "animator", in order to allow GM crop introduction that other players could not predict.

We did not impose rules other than the legal threshold and the principle of responsibility for the GM producer. The reasons for this choice were twofold: no legislative framework was available at the time of the study and therefore could not be tested, and the imposition of a rigid framework, for example compulsory isolation distances, would have been incompatible with our goal to acquire knowledge about actors' organisation and decision-making.

Table 1: resources allocated to players and commercial outlets

Alsace - maize	
Stakeholder	**Ressources**
6 cereal farmers; 1 cattle breeder	Land (42 to 223 ha); 3 farmers own a combine harvester
1 work contractor	2 combine harvesters
2 grain merchants	Storage capacity (respectively 1 silo with 2 cells and 2 silos with 2 cells)
1 technical adviser	List of measures players could implement
All	Empty field maps and information coming from the research team if asked
Name of the outlet	**Marquet requirement (% of GM ingredient)**
Animal feed	-
Conventional	< 0.9%
Starch	< 0.4%
High quality starch	< 0.1%
	Beauce - oilseed rape
Stakeholder	**Ressources**
6 cereal farmers	Land (30 to 50 ha); combine harvesters owned by 4 farmers, shared by 2 farmers
2 grain merchants	Storage capacity (respectively 2 silos with 1 cell and 1 silo with 2 cells)
1 technical adviser	Vulgarisation paper on coexistence on oilseed rape
All	Empty field maps and information coming from the research team if asked
Name of the outlet	**Marquet requirement (% of GM ingredient)**
GM	-
Non GM	< 0.9%

Both games in Beauce and Alsace took place in one day. The players were gathered in the room by roles. Two rounds were held for each game, one with low GM pressure in the landscape and low level of information, the second with a higher GM pressure and level of information (Table 2). The results of simulations at the field and silo levels were presented after each round. At the end of the day, the results and the realism of the game were discussed during a debriefing.

Each round was divided into three steps:

- sowing: farmers allocated crops and GM and non-GM varieties to fields. It was possible to implement preventive measures (non-GM buffers around GM fields, and of course field allocation ensuring isolation distance).

Crop allocation was subject to the following rules:

In Beauce, the farmers had the choice to sow OSR wheat or barley. A map of the crops in place the previous year was provided to farmers, and it was said that the most profitable rotation in the region was OSR-wheat-barley. In consequence, farmers were prone to sow OSR after barley, although it was not imposed. In Alsace, the farmers had the choice between maize or other crops as a generic category. They were free to sow maize where they wanted, with the only constraint of less than 90% of maize in the agricultural area, except for one farmer breeding cattle for whom the rate was 40%.

Table 2: contexts of the games

Alsace - Maize			
Context	**Zone at risk of disease (ha)**	**Probability of yield reduction in case of non-GM maize growing**	**Availability of information**
1st round	0	0	After sowing and before harvest at the regional level (percentage of GM maize in the whole landscape)
2d round	77	1/3	After sowing and before harvest at the field level (the location of each GM field is known)

Beauce - oilseed rape		
Context	**GM percentage in the landscape**	**Availability of information**
1sd round	20% GM OSR : one farmer gets GM seeds	After sowing it is rumored that 20% of the OSR has been sown with GM varieties
2d round	50% GM OSR : 2 farmers gets GM seed for all of their OSR fields, one only for half	Before sowing, it is rumored that 50% of the OSR will be sown with GM varieties

The choice of sowing GM or non-GM varieties depended on the crop: in Beauce, the choice was guided by the distribution of GM seeds to some farmers at the beginning of the game. In Alsace, the choice was guided by risk of corn borer attack and the probability of yield loss, except for the farmer played by the animator who had to sow a quota of GM seeds. The information on the risk of attack was provided at the beginning of the game with a risk map.

- Harvest: farmers and contractors harvested during a period of 10 days (Alsace) or 6 days (Beauce), it was possible to discard strips in non-GM fields, i.e. harvested separately and put in GM grain batches.

- Grain collection: grain merchants allocated harvests coming from fields to their storage cells and could ask for DNA analysis. The cell content was then assigned to various outlets. The cells were emptied every two days (Beauce) or daily (Alsace).

At each of these three steps, players' decisions (crop allocation, harvest planning and grain collection management) were written on paper sheets, which were input data for the simulations performed with a meta-model.

2.2. The meta-model

The development of a meta-model allowed us to calculate and represent the consequences of decisions taken by the players (Figure 1). This meta-model was based mainly on the gene flow simulators MAPOD maize (Angevin et al., 2008) and GENESYS Colza (Colbach et al. 2001a and 2001b), and performed the following calculations: harvest pollution at the field level due to gene flow, integration of the impact of non GM-buffers around GM fields; admixtures in harvest machinery; aggregation in silos and traded grain batches.

On maize, gene flow simulations were not achieved in game, but previously used to establish a matrix of results, from which it was possible to calculate the contributions of each GM field of the landscape to the pollution of a given conventional field. In the case of OSR, admixtures at the field level were obtained directly in game by GENESYS.

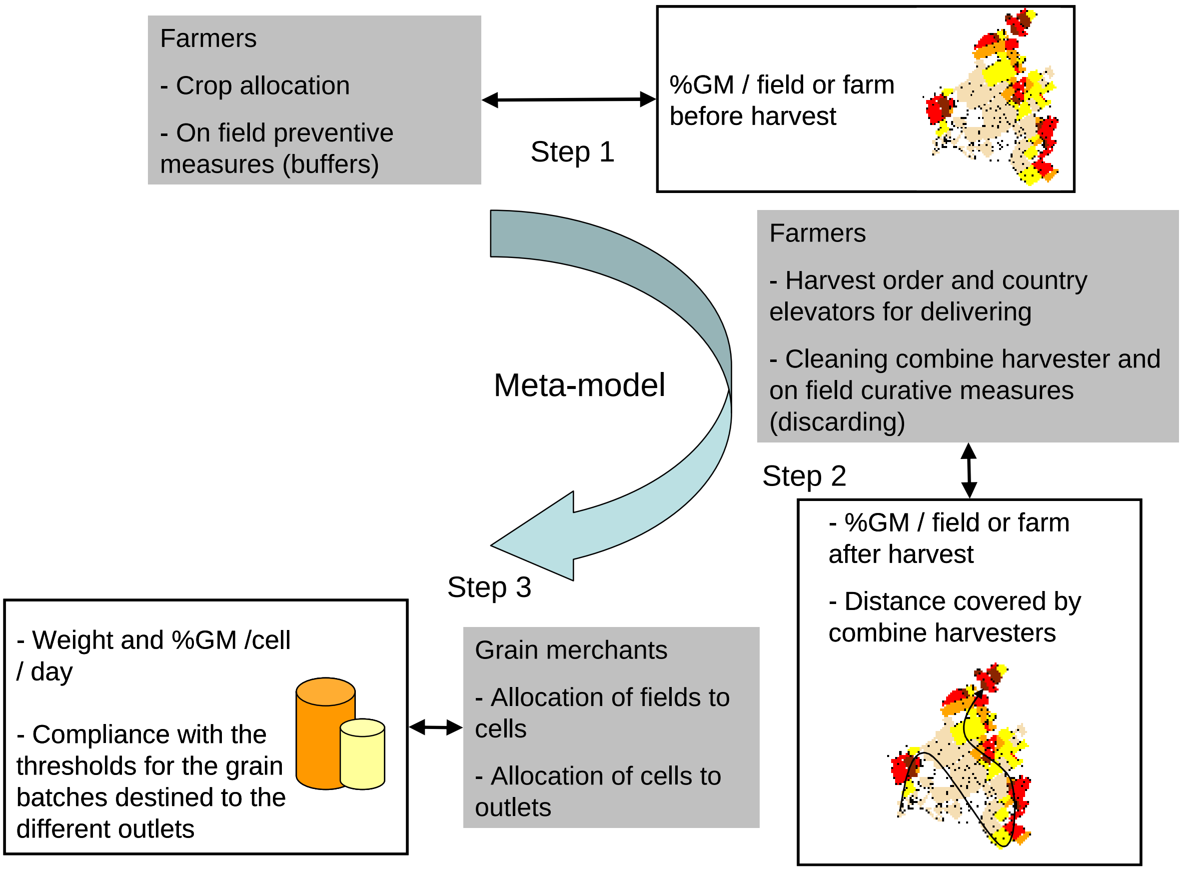

Figure 1: different steps of the simulation process - inputs are in grey boxes; outputs are in blank boxes; %GM means the ratio (number of GM grain / total number of grain) in conventional harvest

2.3 Data analysis

Several types of data were collected at the end of games:

- The simulation results;

- Records of all actions taken by the players, including the possible coexistence measures;

- The maps drawn up by the players, with the help of freely distributed empty field maps;

- Sound recordings and notes taken during the game allowed us to gain additional information on the motivations of the decisions taken by the players, and major events that punctuated the games (alliances, sharing of information, misunderstandings, coordination meetings, etc.).

With these data, we were able to track what the players played, with the corresponding technical results, but also the determinants of their actions. Decision rules were identified for each stage of the game, and for the implementation of specific measures to manage coexistence, with particular attention to the nature and flow of information. The scenarios were constructed by using these results to enrich those obtained in the course of the previous step of the study.

3. Results

3.1. Main results of the games

3.1.1. How did the stakeholders manage coexistence?

After analysing the game results, we identified three means used by actors to achieve their goals. First of all, the coordination between actors may affect the coherence and efficiency of their own strategies. This coordination concerned the following items: information sharing, decision rules and resources (manpower, equipment) to manage coexistence. Secondly, the availability of information was a bottleneck impeding certain coexistence strategies. Lastly, a learning process could allow the implementation of more efficient strategies over the years.

Coordination

Grain merchants were very sensitive to their customers' requirements and tended to adopt strategies aiming at selecting and possibly downgrading field harvests, based on a risk assessment. To do so, they actively sought information to classify fields according to three categories: "GM", "conventional", "doubtful", i.e. likely to be polluted. This information was acquired between sowing and harvesting, at the field or farm level. The assessment of a possible risk could lead to downgrade the field harvest or assign it to a less profitable outlet. This kind of decision was taken unilaterally by the grain merchants.

Farmers sought to protect themselves from a possible loss of harvest quality. This was particularly visible in Beauce, where measures were implemented at the field level, preventively at sowing (field voluntarily isolated at the periphery of the map, protective non-GM buffers around GM fields) or curatively at harvest (non-GM strips harvested separately and downgraded). In Alsace, farmers were less active and only two measures were taken to isolate whole farms preventively: the cooperative asked a farmer to gather his GM fields at the periphery of the map; another farmer allocated crops other than maize close to a "doubtful" farm, as a sanitary cordon.

The planning of harvest and grain collection was the result of intense exchanges between farmers and grain merchants. In Beauce, farmers established their own plannings to ensure that the GM crops were harvested after conventional, and grain merchants got organised accordingly. As the pollution of GM harvests by conventional had no economic consequence, this strategy made the cleaning of combine harvesters and silo unnecessary. In Alsace, the planning was made in a much more directive way. After the announcement that GM crops had been sown in the region, the grain merchants designed together a grain collection planning in order to separate the collection of conventional from GM products, by delaying the delivery of the latter to the end of the season as done in Beauce. Five versions of this planning were successively proposed, after interactions with the farmers and the contractor, who finally incorporated this constraint in their own harvest planning. This process highlighted some conflict of interest. If the farmers wanted some flexibility, the contractor wanted the grain merchants to plan the same opening days for the GM and conventional harvests. The contractor finally had great difficulties to plan his harvests. In the second round, the same strategy aiming at collecting GM after conventional crops was implemented, but this time without consultation with the farmers and the contractor. Farmers and grain merchants decided to plan their harvests along a gradient of risk, in order to harvest the "doubtful" after the "conventional" crop. But this rule proved to be difficult to apply, especially for the contractor who was subject to other constraints (capacity per day, distance) and was not well-connected to the information flow between the grain merchants and the farmers.

Mistakes were made, both in Beauce and in Alsace, due to coordination failures: misreading by the farmer of the delivery schedule set up by the grain merchants, or on the other hand ignorance by the grain merchants of the protective measures implemented by the farmer. For example, a conventional OSR harvest was downgraded without taking a buffer created by the farmer into account, because this information had not been forwarded to the cooperative.

Information Management

Despite the physical proximity of the players and the availability of empty field maps, the practical problems posed by the acquisition and distribution of information were not completely solved. In all cases, we found asymmetry in the information flow at the expense of farmers who provided information, and for the benefit of grain merchants who consumed it. The grain merchants' involvement was variable, but in both cases they were at the central point of the information network. In Alsace more than in Beauce, information on neighbours' activities passed by the grain merchants. Grain merchants did not share information in Alsace, and occasionally in Beauce.

The early availability of information in the second round facilitated the implementation of preventive measures in Beauce. However, this advantage had not really been exploited in Alsace, except a request made by the grain merchants to a GM grower to group and put his GM fields on the periphery of the map. In both cases, players had more time to assess risks at the field level.

Learning process

We have seen a learning process between the two rounds, but also during each round. The risk assessment evolved in response to various information.

- Information provided by the technical advisers: the technical advisers remained rather quiet and were not involved as we expected. Technical information provided to advisers at the beginning of the game was not broadcast automatically to other players. In Alsace, the adviser, specialised in mixed farming and cattle, was uneasy with the technical aspects of coexistence and did not interfere much with other players. In Beauce in the first round, the adviser broadcast information on a 200 m isolation distance for "security". Before the second round, he convened an information meeting during which an expert from CETIOM, in fact a member of the research team belonging to this institute, was invited and spoke on the possible management measures, i.e. in most cases on field flexible measures were sufficient to reduce risks.

- Feedback during the game: in Beauce, pessimistic risk assessments established by a grain merchant with a first distance of 200 m were updated following the disclosure of simulation results at the field level, which could be interpreted as results of analysis : harvests initially classified as "doubtful" were reclassified as "conventional". On the other hand, in Alsace, after the transmission of analysis results, one grain merchant decided not to allocate the "conventional" to the high quality market, but chose the intermediate starch market.

- Feedback after the results of the first round: In Alsace, during the first round, the risk of GM presence at the field level was assessed thanks to information concerning the adjacent fields, or when not available the adjacent farm. The simulation results presented after the first round were used to refine the risk assessment taking into account the distance and the number of GM fields in the neighbourhood as well as the field areas and the wind. The results of the first round in Beauce helped the players to better assess the risk level according to distances between fields and made them more aware of the importance of information.

3.1.2. Simulation results

The table 3 shows the simulation results. The compliance to the market requirements of the grain batches coming out from silos is the final indicator to assess the achievement of coexistence in these games. From this point of view, the only problem occurred when a grain merchant took the risk of the starch market without enough information on his product. At the field level, harvest quality improved in Beauce between the two rounds. It is a remarkable result given the higher GM pressure in the landscape. This improvement was due to the implementation of measures at the field level. It is not possible to distinguish whether these measures resulted from a learning process, or from earlier availability of information. It nevertheless demonstrates the potential adjustment of management methods.

Table 3: simulation results

		1st round	2nd round
Beauce - OSR	GM OSR area / total OSR area	20%	50%
	Non-GM fields > 0.9%	16%	9%
	Non-GM fields < 0.9%	84%	91%
	Grain batches not compliant with the conventional market	0	0
Alsace - maize	GM maize area / total maize area	18%	43%
	Non-GM fields > 0.9%	7%	13%
	Non-GM fields between 0.1 and 0.9%	40%	59%
	Non-GM fields < 0.1%	53%	28%
	Grain batches not compliant with the high quality starch market	0	-*
	Grain batches not compliant with the starch market	37%	-*
	Grain batches not compliant with the feed market	0	-*

* grain collection step not completed

3.2. Debriefing

In Beauce, participants felt that the logistic problems had been overestimated because the OSR is generally harvested early in the campaign and does not pose a big problem of storage capacity. The downgrading of conventional product played by one grain merchant due to low storage capacity was considered unlikely. Finally, in both regions, the grain merchants did not plan to share their storage capacities.

The cost of coexistence measures was discussed, as well as the financial support to compensate downgrading. Solutions negotiated between farmers had been proposed in Beauce, for example, the establishment of compensation tables with the help of a third party, namely the Agricultural Chamber, allowing compensation for loss due to discarded zones or the work done by a neighbour to implement a buffer zone. A mutualist system was mentioned, as well as the supervision of the GM crop cultivation and traceability thanks to private contracts. However, these contracting practices, although in extension, are used for small markets, and thus raise problems of generalisation.

The availability and flow of information was considered more favorable than in reality because of the physical proximity of the players and the availability of field maps provided by the research team. In real situations, problems of synchronisation would occur frequently when the decisions are taken in an iterative process, for sowing or harvesting, as illustrated by the difficulties to plan harvest and grain collection in Alsace.

However, the absence of information on the varieties sown in the first rounds was estimated unrealistic, because cooperatives know the quantities of seeds they sold to their members. In some cases (for example HEAR) they can influence the farmers' choice to make it compatible with a given strategy of dedicated silos.

Finally, the feasibility of quantitative DNA analysis was considered as a crucial point. In situations of doubt about the quality of the product entering the silo, the quality monitoring would be greatly facilitated by a real time analysis.

The simplifications pointed out by the debriefing were not considered too embarrassing by the participants. They admitted the method encouraged their active participation, probably better than could have done other more usual participative methods.

3.3. Proposition of scenarios

As results of previous steps in the SIGMEA project, for each landscape, threshold and introduction rate of GM, we could identify different risk levels at the field and silo levels (Sausse et al., 2007, Lebail et al. Submitted). This information crossed with the results of role-playing games provided a general model to identify contrasting scenarios: they will depend not only on the structural risk level, but also on the possibility of coordinating and having access to information.

Scenario I with low to moderate admixture risk. A segregation based for example on different dates of grain collection or on dedicated silos is enough to ensure the market requirements. The easiest case is the management of two products: GM or conventional (scenario I1). However, if highly demanding markets are targeted with thresholds lower than 0.9%, the stakeholders may create an intermediate category of product that may be downgraded, coming from non-GM fields at risk (scenario I2)

Scenario II with high admixture risk and large access to information and coordination ability. Farmers will coordinate to implement preventive measures (isolation distance or buffer strips), or corrective measures in case of failure (discarding and downgrading conventionnal harvest).

Scenario III with high admixture risk and low access to information and coordination ability. Some farms are classified as "at risk", which brings about increasing opportunities for downgrading harvests.

Scenario IV where the risks and the possibility of coordinating and having access to information are such that no coexistence is possible. This is for example possible if the field pattern does not allow to reach a contractual threshold lower than 0.9%.

For a given landscape and risk level, scenarios may evolve over time as a result of a learning process, in which the risk assessment as well as information management and sharing will be progressively refined. Figure 2 provides a general model for the classification of coexistence scenarios according to 3 axes: structural risk, possibility of coordinating and managing information, and time.

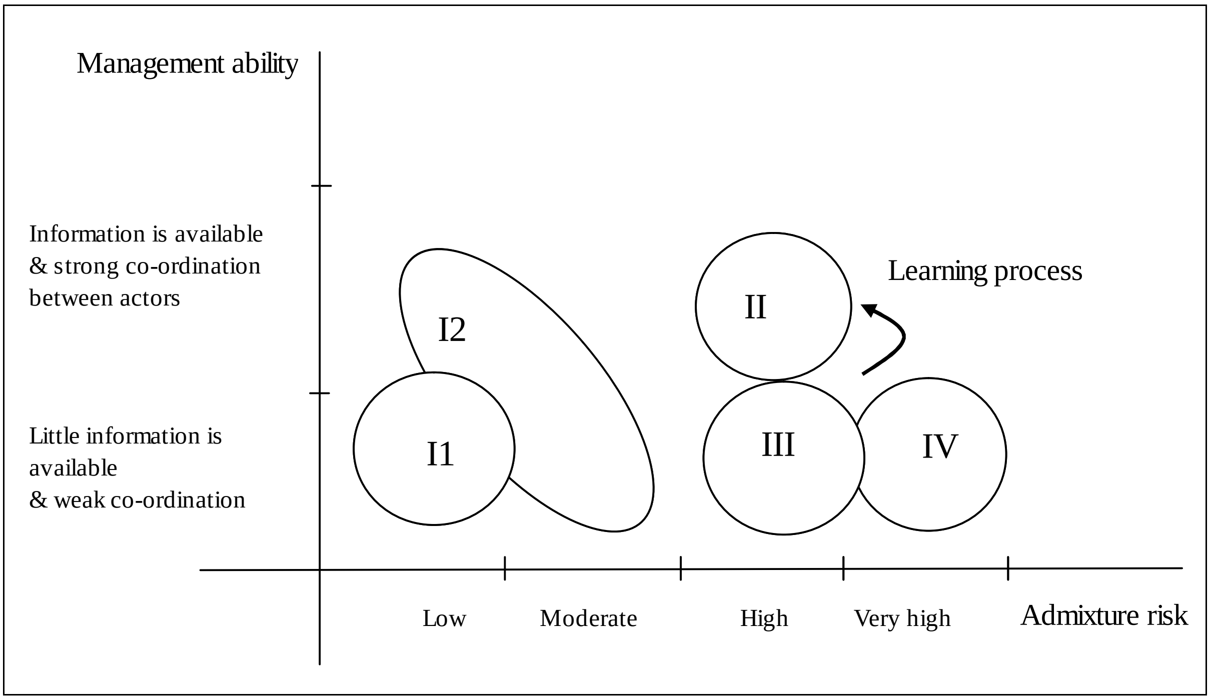

Figure 2: proposal of generic scenarios for coexistence. I: segregation at the silo level without measures at the field level (I1: segregation between GM and non GM; I2: an intermediate category "at risk" may be created); II: preventive and/or curative measures are implemented at the field level; III: whole farms possibly classified "at risk"; IV: no coexistence possible

4. Discussion

An important issue raised by the games is the acceptability of the downgrading strategies (preventive allocation of non-GM grain batches to GM or less profitable markets) spontaneously used by the grain merchants. Downgrading harvests has a cost equal to the difference in price between products intended for the different markets, for example GM and non-GM. This cost may correspond to real differences in grain quality or reflect an "overquality", when the product would have been declared compliant in case of analysis. Two elements should be considered. First, the professional know-how for the management of grain quality has been developed in contexts where farmers were responsible for their products with possible price penalties justified by inappropriate agricultural practices. The case of GMOs is different because the responsibility for non-compliance may come from the neighbours. Participants were aware of this fact although they did not integrate it into the practice revealed by the games. Secondly, the non-compliance of a commercial grain batch coming from a whole silo is a serious event for the grain merchants in terms of financial and reputational loss, compared to the problems posed by downgrading a farmer's harvest. We observed that this risk asymmetry justified precautionary measures at the expense of individual farmers. Finally, downgrading raises the problem of possible financial compensations. The few tracks mentioned during the debriefing suggested that the participants were open-minded and flexible to face this challenge.

The legal status of the "dilution" is another open question. The scenario I involves a dilution process of the GM grains from the field to the silo. But it is not easy to determine if it is allowed or not. Much will depend on its "adventitious" nature and thus on the ability of grain merchants to obtain information on DNA quantification at the silo entrance, which is a technical challenge to be solved. The natural tendency, if the admixture risk is considered low, would be to avoid analyses at the silo entrance, which is costly and could lead to downgrading, and to focus solely on analyses at the chain end, thus certifying the quality of the grain batch to customers. This issue refers to the operational objective of coexistence: strict management of food quality (like fatty acid or starch content), or preventing the spread of genes considered as contaminants in the environment and the food chain (like heavy metals or pesticides). The legislative and regulatory texts are not explicit about this. Another unresolved issue is the feasibility of analysis that will determine the risk assessment and subsequent management strategies. In this regard, gene flow simulators currently developed could establish alternatives if necessary information is available.

The scenarios we produced cannot be considered as models of what should be implemented for managing coexistence. As stated in the introduction, our methodology aimed at describing how a "bottom-up" coordination process emerged and purchased a cognitive rather than normative goal. These results question the "top-down" strategy so far considered by decision makers: in addition to the technical and economic problems posed by the rigidity of measures, neglecting the usual practices of grain quality management could be counterproductive. Indeed, the challenge of flexibility is to invest in gaining information to adapt management measures for better economic efficiency (avoiding product downgrading and unnecessary measures). For example, it might be useful to combine the administrative reporting system of GM crop areas with the information network implemented by professionals, in order to avoid duplications and subsequent costs.

6. Conclusion

Coexistence is not only a matter of structural risk related to geographic, biological and technical parameters. It is also a matter of coordinating and managing information. The latter must be regarded as a resource and a subject of investigation as relevant as can be the gene flow. In addition, the practicality of co-existence can be defined only if there is a consensus on its operational objectives: food quality management or avoiding gene flow into the environment.

The results lead us to reformulate the starting question: the problem of coexistence is not to define what is the "best" measure, but to fluidify access to information between farmers, and between farmers and grain merchants, to ensure efficient management by reducing costs. The other issue is how to articulate the rigidity of the regulation and what players are used to practice in the management of grain quality. Between "top-down" and "bottom-up" governances, can you imagine a third way?

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