A SIMULATION MODEL TO EVALUATE THE EFFECT OF COOPERATION BETWEEN GRAIN MERCHANTS IN MANAGING GM AND NON-GM SEGREGATION FOR MAIZE IN EUROPE

F.C. Coléno[1] and M. Hannachi[1,2]
[1]INRA UMR 1048 SAD-APT
[2]Larequoi, Université Versailles-St Quentin

Abstract

GM and non-GM coexistence, as defined by the European commission, defines a product as non-GM if it contains less than 0.9% of GM material. A good solution to avoid the risk of mixing GM and non-GM in the landscape and during collection process is to define homogeneous production zone for GM and non GM. To allow such zone to be defined cooperation between grain merchants is needed. In this paper we want to evaluate if such cooperation have an interest for grain collection management. To do so we used a simulation model of the collection process. The simulation shows that such cooperation between companies allows them to collect more non GM product than the situation where they operate separately.

Keywords: GM and non GM coexistence, cooperation, simulation model

Subtheme: farm management

1. Introduction

The prospect of growing GM crops in Europe generated conflict between proponents and opponents of this technology (Levidow et al., 2000), leading at first to a moratorium on GM crops. This ended in 2004, since when both types of crop have co-existed in the landscape, with GM and non-GM material segregated in the supply-chain. Several European regulations define the rules of coexistence and segregation:

- For the consumer's information the aims of these regulation is to guarantee that any food containing material that contains more than 0.9% of GM would be labelled "contains GM" (EC 2003a).
- for the food industry the objective is to enable GM products to be traced throughout the supply chain ("from farmer to fork") (EC, 2003b),
- At the level of agricultural production, this regulation concerns the release into the environment of GMO (EC, 2001) and so to avoid cross-pollination between GM and non-GM crops (EC, 2003c).

For agricultural production, this coexistence generates several problems. On a farm, use of the same agricultural machinery, such as a seed drill or harvester, for both GM and conventional production, increases the risk of admixture (Jank et al. 2006). Moreover, a farmer using GM seed has to be sure that his fields will not contaminate the conventional production of his neighbours. This can be done in two ways. The first is to have an isolation distance between GM and non-GM fields (Byrne and Fromherz, 2003) because maize pollen has a short dispersal range (Della Porta et al, 2008). The second is to ensure a time lag between the growth of GM and non-GM crops so that they do not flower simultaneously (Messan et al., 2006).

At the industry level, the problem is to guarantee the level of GM material in the product. This is done using risk management policies such as HACCP (Scipioni et al. 2005) or IFMEA (Arvanitoyannis and Savelides, 2007) combined with testing procedures using quantitative methods such as the PCR test (Lüthy 1999; Arvanitoyannis, 2006)

For maize production, the link between industry and farms is the grain merchant whose infrastructure is the site of the highest mixing risk between GM and non-GM corps (Le Bail and Valceschini, 2004). Several critical features have been identified in this collection chain (Bullock and Dequilbet, 2002; Le Bail, 2003), concerned with cropping plan management, storage of harvested products and, in the case of maize, drying, which is a bottleneck in maize collection. These critical points are linked with the fact that grain merchants have to combine the production of several dozen fields in their collection silos and maize dryers. Furthermore, the batches obtained must be dealt with in less than 48 hours to protect the maize quality (Coléno et al., 2005). It is thus not possible to exclude batches by using the PCR test, which takes more than 48h. Moreover, the large investment necessary for the implementation of two isolated collection chains means that the GM and non-GM products need to be segregated using the existing infrastructure. Two possible strategies have been identified to segregate the two products (Le Bail, 2003, Miraglia et al., 2004; Coléno et al., 2005). These strategies are based on:

- The separation of the two products in space, allocating one chain to each type of crop, so that each collection silo receives only one type of product. Dryers are also allocated to one type of product.
- The separation of the two products by the timing of their deliveries. In this case, each product is delivered to the nearest collection silo to the farm, but at a specific time. Thus, non-GM grain can be delivered in the beginning of the collection period and GM at the end. There is no risk of mixing between non-GM and GM, which might lead to downgrading of the non-GM crop.

The efficiency of these two strategies has been evaluated (Coléno, 2008). It has been shown that the time strategies allowed to minimise the segregation cost but did not allow maximising the quantity of non-GM product collected. On the contrary, the spatial strategy is more costly but allows a greater amount of non-GM collected.

Moreover, these strategies do not have the same effect on landscape organization and on the risk of cross-pollination between GM and non-GM fields. The spatial strategy could allocate parts of the landscape to each crop and thus minimize accidental GM presence, which is not possible with the temporal strategy (Coléno et al., 2009). Grain merchants have a key role in creating such homogeneous zones for GM and non-GM production. They can influence farmers' cultivar choices using production contracts and price differences between crops. But if there is more than one grain merchant operating in any given region they would have to cooperate to create a homogenous zone of sufficient size; otherwise it would not be big enough to ensure a sufficiently low threshold in the non-GM batches collected (Coleno et al., 2009).

Such cooperation between companies could improve to the efficiency of segregation of the two products during the collection process. In this paper we want to explore this hypothesis using a model of grain flow simulation in the collection process. After presenting the model, we will evaluate a case where two companies cooperate by sharing their infrastructure and a case where theses two companies did not cooperate. To do this evaluation we used using two criteria: the collection cost and the proportion of non-GM that is stored as non-GM at the end of the collection process.

2.   The GM and non-GM maize collection chain

Maize collection in Europe occurs in autumn - generally from September to December. During this period, farmers harvest their maize and deliver it to the collection silos of the firm purchasing their harvest. Each of these silos is made up of different cells, all of the same size. The cells are small compared to the quantity of maize collected. Very often, maize is transferred from collection silos to dryers. When maize is dried, it is stored in uniform batches in storage silos in seaports or railway

stations. These storage silos may contain 300 000 tons or more. To ensure a high quality of maize, and hence access to the best food markets, the maximum time from harvesting to drying should be less than 48 hours. To ensure GM and non-GM segregation in the collection chain, several factors have been shown to be important (Le Bail 2003; Coléno et al 2005):

- Mixing of products can occur in the collection silos. When all the cells contain maize the silo manager has to choose between (i) accepting farmers' deliveries and thus mixing the two products or (ii) refusing some deliveries to avoid mixing but with the risk that the farmer will sell his crop to another firm. The type of relationship between the firm and the farmer, and whether there is another grain merchant in the vicinity will influence the silo manager's decision.
- Mixing may also occur in the dryers. To reduce drying costs, dryers are used at their full capacity. In so doing, mixing may occur if there is not enough of one product. Moreover, to avoid contamination between products in the dryer, the first batch of non-GM that follows a GM lot must be sold as GM.

3.   Presentation of the model (Coleno, 2008)

The model deals with these two critical points and takes into account transport between collection silos and dryers. It is therefore made up of three modules: collection silos, dryers and transport.

In order to take into account the decentralized method we will consider two scheduling of collections silos and dryers. The first one, in favour of segregation, consists of making uniform batches, while the second focuses on cost minimization using the total storage and drying capacity.

3.1   Collection silos
Each day, a collection silo receives a quantity of GM and non-GM maize. If there is one cell that already contains the product delivered, the delivery is put into this cell if there is room. Once it is full, the rest is put in another cell containing the same product, or in an empty one. If there is no such cell, the management of the rest will depend on the scheduling of the collection silo:

- In the case of a scheduling in favour of segregation (SS1) the rest will be refused and deferred to the next day.
- In the case of a scheduling in favour of cost minimisation (SS2) the rest will be put in the first cell with sufficient free space. The maize in this cell will then be considered as GM.

3.2   Transport
Each day, the collection silos can call for transport if their stock is above a certain threshold. These requests are treated using the First In First Out management rule, the older batch being given priority. To take into account the time constraint of 48 hours for the food market, the delivery stocked at t-1 has the higher priority level. If it is not possible to store the incoming batch in the waiting silos at the drying facility, the delivery is deferred to the next day.

3.3   Dryers
Drying facilities consist of two structures: dryer waiting silos, where maize is stored before being dried, and the actual dryers. Each day, a dryer dries one batch of maize. The management of dryers depends on their scheduling:

- In the case of a scheduling in favour of segregation (SD1) drying batches are uniform, and so contain only one type of product, even if the dryer is not used at its full capacity.
- In the case of a scheduling in favour of cost minimisation (SD2), mixing of GM and non-GM takes place as soon as there is not enough of one product to use the dryer's full capacity. In this case the batch dried is treated as GM.

Moreover, the dryer is managed to minimize the change of products from one day to another in order to minimise the amount of non-GM to be treated as GM.

3.4   Variables used for simulation

The model runs with a daily time step. Each day, collection silo stocks are calculated, taking into account the GM and non-GM deliveries. GM and non-GM quantities dried are calculated, taking into account the waiting stock at the drying facility. From these new values of stocks in collection silos and dryer waiting silos, transport of maize from collection silos to drying facilities is calculated.

We first simulated the collection with only one product collected in order to compare the cost of a situation with segregation with the present situation (without segregation). The deliveries per day for the whole collection period in this case are shown in figure 1. This curve is the ideal situation for grain merchants. It arises from the combination of an optimal management of grain maturity and the desire of farmers and grain merchants to harvest maize when it is as dry as possible.
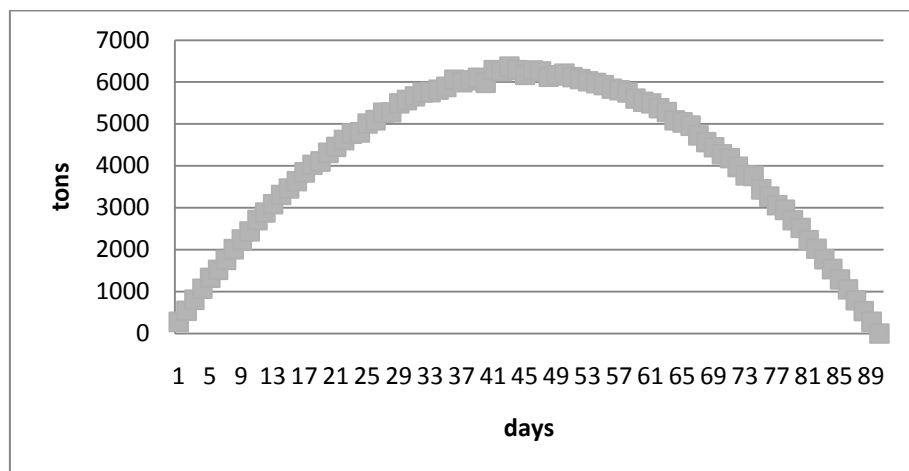

Figure 1: grain deliveries (GM and non GM) during the collection period

We ran a simulation with two grain merchants. One owns 1 dryer and 5 silos; the other owns 4 dryers and 20 silos. By way of comparison we also made a simulation with 5 dryers and 25 silos. This simulation allows us to compare the cost between the situations with and without segregation. For each of these situations we considered three distributions of GM and non-GM products in the deliveries (non-GM representing 25, 33 and 50 % of the total deliveries). Beyond 50 % of non-GM in the total deliveries, the results would be reversed between non-GM and GM because the question would be to isolate 25, 33 or 50 % of GM. For each of these three situations we compared the quantity of each product (GM and non-GM) at the end of the process to the quantity of the product delivered. To do so we calculated the ratio between these two values. To consider the cost we compared (i) the increase in transport cost compared with the situation with one product and (ii) the rate of dryer use, which is a good indicator of drying cost, as this cost is almost independent of the quantity dried.

4.   Results

Figure 2 shows the ratio between GM and non-GM at the end of the collection process and GM and non-GM at the beginning of the process. It is so possible that this ratio exceed 100% if some of the non-GM product was mixed with product.
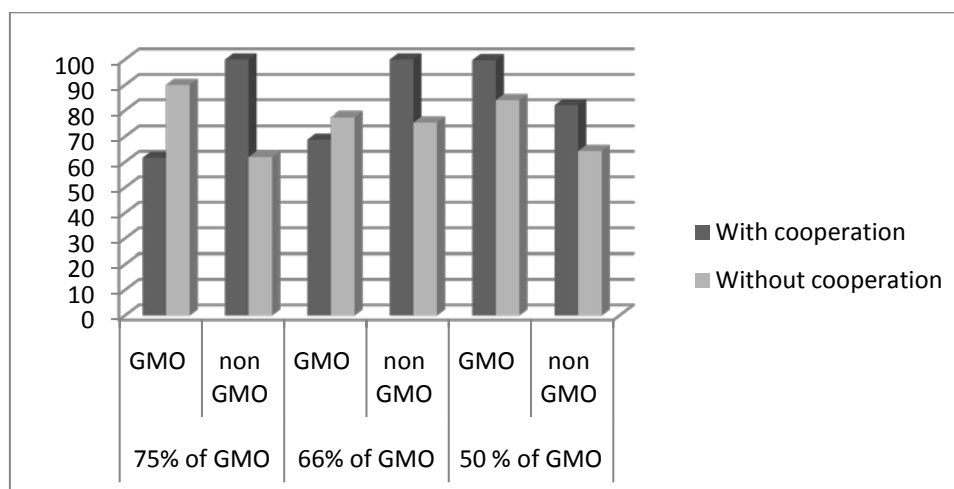
Figure 2: level of GM and non-GM product at the end of the process compared to GM and non-GM product delivered to grain merchant at the beginning of the process

We first cans see than in any cases a segregation policy do not allow companies to treat all the maize they collect in the time of 90 days. As our model stop the calculation at 90 days there is still maize in the process. This explains why 12% of the GM and 40% of the non-GM crops is not included in the figure with 75% GM and without cooperation. In total 25-60% of the entire crops (GM and non GM) are not dried within 90 days. The 50-50% option with cooperation has the most materiel which is ready after 90 days. In the real life the companies will steal dry the maize and sell it at a lower price, because of a lack of quality.

We can see that in any case the situation where the two companies cooperate is more efficient than when they do not. When there is 75% or 66% of GMO in the collection there is 100% of the non-GM collected at the end of the process. This level falls to 80% when there is 50% of GMO in the collection. Conversely when the two companies do not cooperate we can see that the level of the non-GM segregated is never more than 75%. The rest of the non-GM is therefore sold as GM as shown by the level of GM product at the end of the process which is over 100%.

As to collection costs, figure 3 shows the increase in collection cost when there is segregation compared with a case where there is only one product collected by two companies[1]. This increase is calculated by a comparison with a collection of the same size with only one product. We see that segregation increases the transportation cost in any cases and that in the case of cooperation the cost increase is lower with 50% of GMO than in the other cases. This due to the fact that in that case there are 2 dryers for one product and 3 for the other one so the amount grain treated is higher. There is so more grain transported to the dryers and so the transportation cost per ton is lower.

Moreover the transportation cost increase is greater when the two companies cooperate than when they do not. When the two companies cooperate to segregate the product, GM non-GM products is delivered to specific dryers, it is so not possible to deliver batches from collection silos to the closest dryers. The minimization of the transportation cost is then impossible. On the contrary when there is no cooperation between the companies, the one with only one dryer deliver all the maize is delivered to this dryer located closer to the collection silos owned by the company.

---

[1] The calculation of this cost increase is made using this formula: (cost with segregation per ton – cost with one product per ton) /cost with one product per ton *100. So if the cost with two products is the same than the cost with one product the increase equal zero.
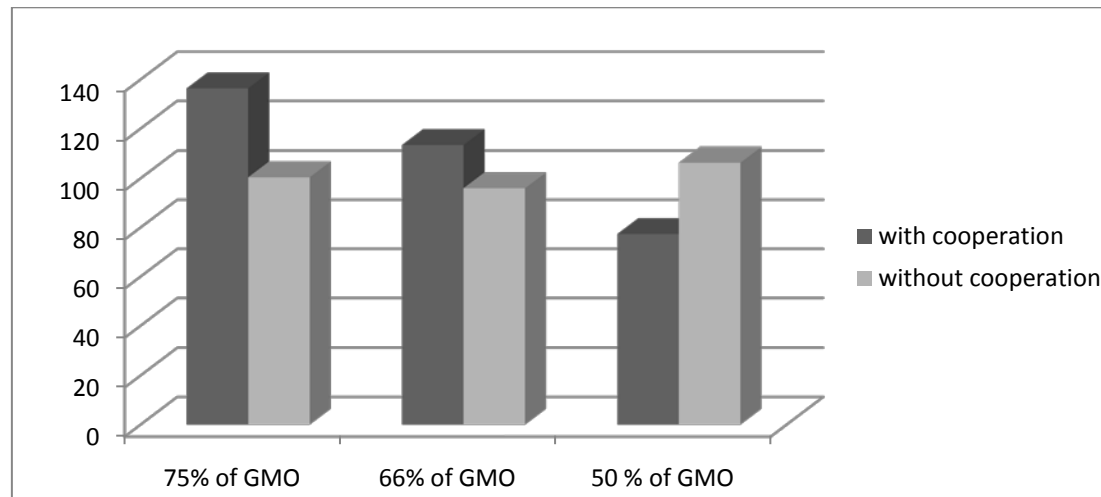
Figure 3: cost increase due to segregation for the two cooperation strategies

5.   Discussion and conclusion

The implementation of such a cooperation strategy between rival companies requires an information system allowing the various companies to know exactly the quantities of products stored in their name in their competitors' silos. This information system has to ensure confidentiality on the strategic data of companies. The management of this information thus requires a third party which has the confidence of all the companies and which is able to ensure, at a given moment, the collection and sharing of the information needed by all the companies. The question of the importance of such an information system and the difficulties of its implementation has already been investigated in other agricultural fields, specifically for high-value products with a high level of competition, such as champagne (Soler and Tanguy, 1998). In the case of GM/non-GM coexistence, management certification companies and supply chain managers have the necessary knowledge to fulfil such a role (Fliedner, 2003) and have shown that they already have the confidence of the various companies in other situations than harvest management.

The coordination between grain merchants for the choice of the specialized production zones (Coléno et al., 2009) and for the management of the harvest collection creates new costs. This increase in the transaction costs will increase the cost of coexistence between GM and non-GM products. Moreover, such a management strategy will lead to a centralization of the collection planning for the whole supply chain: decision rules are imposed on each member of the supply chain (the place of delivery for farmers and trucks and the type of product to be handled for the silo and dryer managers). Such a strategy leads to an increase in the costs for each of the cost centres, as they cannot make rules to reduce them. There is therefore no scope for flexibility in the process, which leads to a big cost increase (Bullock and Desquilbet, 2002).

Acknowledgement

References

Arvanitoyannis, I. S, & Savelides, S.C. 2007. Application of failure mode and effect analysis and cause and effect analysis and Pareto diagram in conjunction with HACCP to a chocolate-producing industry: a case study of tentative GMO detection at pilot plant scale. *International journal of food science and technology* 42, pp 1424-1442

Bullock, D.S. & Desquilbet M. 2002. The economics of non-GMO segregation and identity preservation. *Food Policy* 27, pp 81-99.

Byrne, P. F. & Fromherz, S. 2003. Can GM and Non-GM Crops Coexist? Setting a Precedent in Boulder County, Colorado, USA, *Journal of Food, Agriculture & Environment*, 1 (2), pp 258-261.

Coléno, F. C., le Bail, M. & Raveneau, A. 2005. Segregation of GM and non-GM production at the primary production level. In Messan A. (ed) *proceeding of the Second International Conference on Co-existence between GM and non-GM based agricultural supply chain, Agropolis Production, Montpellier (FRA), 14-15/11/2005*, pp. 169-172.

Coléno F.C. 2008. Simulation and evaluation of GM and non-GM segregation management strategies among European grain merchants. *Journal of Food Engineering*. 88, pp 306-314.

Coléno F.C., Angevin F., Lécroart B. 2009. A model to evaluate the consequences of GM and non-GM segregation scenarios on GM crop placement in the landscape and cross-pollination risk management. *Agricultural Systems*. 101, pp 49-56

Della Porta G., Ederle D., Bucchini L., Prandi, M., Verderio A. & Pozzi C. 2008. Maize pollen mediated gene flow in the Po valley (Italy): Source-recipient distance and effect of flowering time. *European Journal of Agronomy*. 28, pp 255-265

European Commission. 2001. Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC – Commission Declaration Official Journal of the European Union L 106, 17.4.2001, pp. 1–39.

European Commission. 2003a. Commission recommendations of 23 July 2003 on guidelines for the development of national strategies and best practices to ensure the coexistence of genetically modified crops with conventional and organic farming, 2003/556/EC (notified under document number C(2003) 2624). Official Journal of the European Union, 29/07/2003, vol. 46, L189, pp 36-47.

European Commission. 2003b. Regulation (EC) N° 1829 / 2003 of the European Parliament and of the Council of 22 September 03 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC. Official Journal of the European Union, 18/10/2003, vol. 46, L268, pp 1-23

European Commission. 2003c. Regulation (EC) N° 1830 / 2003 of the European Parliament and of the Council of 22 September 03 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC, pp. pp 24-28. Official Journal of the European Union, L268, 18/10/2003, vol. 46, L268.

Fliedner G. 2003. CPFR: An emerging supply chain tool. *Industrial Management & Data Systems,* 103 pp 14-21

Jank, B., Rath, J. and Gaugitsch, H. 2006. Co-existence of agricultural production systems, *Trends in Biotechnology* 24 (5), pp 198-200.

Le Bail, M. 2003. GMO/non-GMO segregation in the supply zone of country elevators, *in proceeding of the first Conference on the co-existence of Genetically Modified Crops with Conventional and Organic Crops*, Borupsgarrd (DNK), 13-14/11/2003 pp. 125-127.

Le Bail, M. & Valceschini, E. 2004. Efficacité et organisation de la séparation OGM/non OGM., *Economie et Société. Série «systèmes agroalimentaires»* 12 (4), pp 18-29.

Levidow, L., Carr, S. & Wield, D. 2000. Genetically modified crops in the European Union: regulatory conflicts as precautionary opportunities, *Journal of Risk Research* 3 (3), pp 189-208.

Lüthy, J. 1999. Detection strategies for food authenticity and genetically modified foods, *Food control* 10, pp 259-361.

Messéan, A., Angevin, F., Gómez-Barbero, M., Menrad, K., & Rodríguez-Cerezo, E. 2006. *New case studies on the coexistence of GM and non-GM crops in European agriculture*. Technical Report Series of the Joint Research Center of the European Commission, EUR 22102 En, 112 p.

Miraglia, M., Berdal, K.G., Brera, C., Corbisier, P., Holst-Jensen, A., Kok, E.J., Marvin, H.J.P., Schimmel, H., Rentsch, J., Van Rie, J.P.P.F. & Zagon, J. 2004. Detection and traceability of genetically modified organisms in the food production chain. *Food and Chemical Toxicology* 42, pp 1157-1180.

Scipioni, A., Saccarola, G., Arena, F. & Alberto, S. 2005. Strategies to assure the absence of GMO in food products application process in a confectionery firm, *Food control* 16, pp 569-578.

Soler, L.G. and Tanguy, H. 1998. Coordination between production and commercial planning : organisational and modelling issues. *International Transactions in Operational Research*, 5 (3), pp 171-188.