A MODEL TO EVALUATE THE FEASIBILITY OF GM AND NON-GM CO-EXISTENCE IN EUROPE AT FARM AND COLLECTION FIRM LEVEL FOR MAIZE.

François Coléno
INRA UMR 1048 SAD-APT
Bâtiment EGER, Site de Grignon, BP 1 78850 Thiverval-Grignon France.
Email : francois.coleno@grignon.inra.fr

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. To avoid the risk of mixing GM and non-GM, we made a model of supply chain management rules and strategies for crop collection planning for a small farming region. It simulates (i) the GM and non-GM proportions at the end of the supply chain and (ii) the transportation and processing costs. Three strategies were evaluated. One has no specific planning. Batches were taken as crops arrived at the silo. A second is on a spatial basis and allocates each silo to a single crop batch. A third is time based and allocates part of the collection time to one product. We show that the spatial strategy allows all the non GM production to be segregated, but at a high cost. On the contrary the time strategy leads to a lower cost but with lower segregation results.

Keywords: GM, supply chain management rules, maize

Introduction

The introduction of genetically modified (GM) crops into Europe has lead to conflict between supporters and opponents of the use of this technology (Levidow et al. 2000). These positions lead to an informal moratorium (since abandoned) on GM use and to several regulations for co-existence between GM and conventional crops, labelling and traceability. This regulation aims to guarantee that conventional production will not become mixed with GM crops. At industrial level, these regulations ensure traceability of GM products at each step of the supply chain, from farmers to consumption. Labelling of GM presence is needed as soon as a product contains more than 0.9% of GM (Arvanitoyannis et al. 2006; Beckmann et al. 2006; Jank et al. 2005).

Concerning agricultural production the co-existence 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 pollute the conventional production of his neighbours. To do so, it is recommended to have a buffer distance between GM and non GM fields (Byrne and Fromherz 2003), and to have time lag between GM and non GM production in order to minimise the risk of pollution (Angevin et al. 2005).

At the industry level, the problem is to guarantee the absence of GM using the PCR test (Lüthy 1999) and using risk management policies. In this case use of HACCP to identify the critical point in the supply chain is recommended (Scipioni et al. 2005).

Concerning agricultural territory, i.e. a small region of several square kilometres, the problem is to propose governance practices that minimise contamination between fields (Byrne and Fromherz 2003), and that allow collection firms to collect the two types of product. These firms have to segregate these two products using the existing infrastructure. This constraint obliges them to combine, in their collection silos and maize dryers, the production of several dozens of fields. Co-existence between GM and non-GM production leads to questions about agricultural production and about transformation and transportation of these products. To answer the first set of questions, several agronomic models of gene dissemination were developed. These models allow the pollution risk from GM fields to be evaluated, taking into account spatial aspects and production system configurations (Angevin et al. 2003). Concerning the second set of question works of Le Bail (2003) identified the critical points in the collection chain. These critical points were concerned with cropping plan management, storage of harvested products and, in the case of maize, drying, which is a bottleneck in maize collection.

At collection level it is possible to consider two different logics in order to ensure chain segregation.

The first consists of using optimal collection scheduling and planning at the different stages of collection (Entrup et al. 2005) to ensure GM and non-GM segregation without any central organisation of product delivery from farmers. A second is a centralisation of the collection decision by organising farmers delivery during the collection period or in the collection territory. This second solution was proposed to manage GM and non-GM segregation where there was a low proportion of GM production. (Le Bail and Valceschini 2004). For a higher proportion of non-GM, such as one third of the whole maize, studies made in collaboration with French collection firms have identified some collection organisation strategies (Coléno et al. 2005). These strategies are based on :

The separation of the two products in space, giving one chain to each production. So each collection silo receives only one type of product. Dryers are allocated to one type of product.

The separation of the two products by the timing of the collection period. In this case, each product is delivered to the nearest collection silo to the farm, but at a specific time. Thus, GM can be delivered in the beginning of the collection period and the non-GM at the end.

In this paper we propose to evaluate these management logics of decentralisation and centralisation using a simulation model of flow in the supply chain of the collection firm for a large proportion of non-GM collected. Concerning the centralisation logic we will take into account the two strategies of segregation in space and time. After presenting the model we will evaluate the different strategies 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.

Presentation of the Model

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 harbours 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. (Coléno et al 2005; Le Bail 2003) :

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 so mixing the two products and (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 collection firm in the territory 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.

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 decentralised logic we will consider two schedulings of collections - silos and dryers. The first one, favouring segregation, consists of making uniform batches. Conversely, the second focuses on cost minimisation using the total storage and drying capacity.

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.

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.

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.

The Model

The model works with a half day time step. Each half 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 and dryer waiting silos, transport of maize from collection silos to drying facilities is calculated.

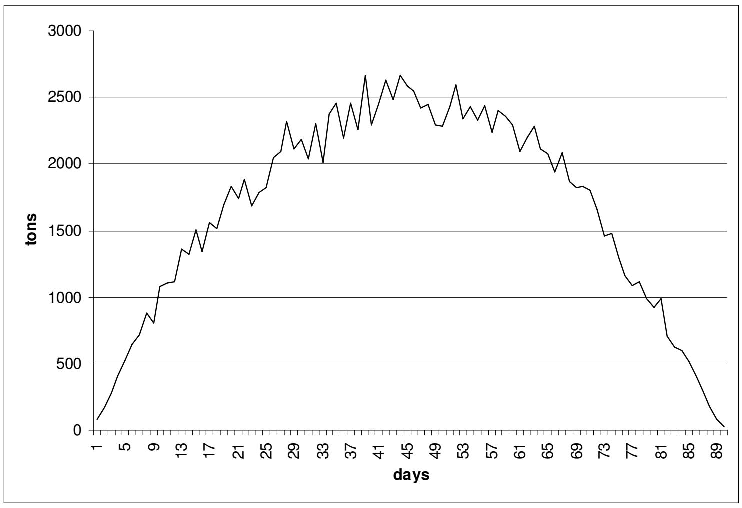
In order to run a simulation, we use the values shown in table 1. These values are the ones we found in the collection firms we worked with. The territory we simulated contains ten collection silos and two dryers.

Table 1: Value of the different parameters

Size of collection silos	4*100 t
Size of dryer waiting silos	2*250 t
Drying capacity	1000 t/ day
Number of trucks	30
Size of trucks	36 t
GM collected	100000 t
Non-GM collected	50000 t

We first simulated the collection with 150000 t of one product in order to compare the cost of a situation with segregation with the present situation. The deliveries per day for the whole collection period are shown in figure 1. This curve is the ideal situation for collection firms. It comes from the combination of an optimal management of grain maturity and the desire of farmers and collection firms to harvest maize when it is as dry as possible.

Figure 1: Deliveries per day for a collection with one product



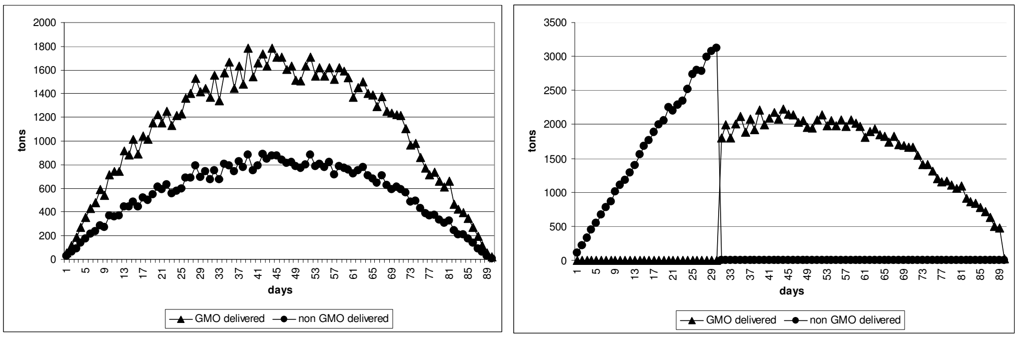
Then we simulated three situations:

One in which farmers can deliver their maize when and where they want.

A **spatial strategy** where farmers can deliver their maize when they want to, but to a specific collection silo depending on the product (GM or non-GM). One third of the collection silos and one dryer were allocated to non-GM products. The curve of delivery for these two situations is shown in figure 2.

A **time strategy** where farmers can deliver their products where they want but non-GM crops are collected only in the first month and GM crops are collected only during the two last months, (figure 2b).

Figure 2: Deliveries per day of GM (▲) and non-GM (●) with no constraint or with spatial organisation (a) or time organisation (b)



a b

For each of these three situations we calculated the ratio of the quantities of product at the end and at the beginning of the collection process. The ratio of GM can therefore be higher than 100% if there is non-GM crop mixed with GM. To consider the cost we compared (i) the increase in transport cost from the situation with one product and (ii) the rate of dryer use, which is a good indicator of drying cost, as this cost is nearly independent of the quantity dried.

Results

Influence of Scheduling Rules

Figure 3 shows the ratio of GM and non-GM crop at the end of the process from GM and non-GM at the beginning of the process. It is so possible to compare the different scheduling rules in the case of a decentralised logic. It shows that the combination of rules which does not favour segregation (SS2 X SD2) allows 20% of the non-GM product to be segregated. This comes from the size of the non-GM collection which is large enough to allow the "natural" constitution of a non-GM homogenous batch. But, if scheduling rules in favour of segregation are used (SS1 X SD1), the ratio of non-GM increases to 50 % for a very small cost increase. The increase in transport cost is zero and dryer use rate is 93 % (table 2).

Figure 3: ratio of GM and non-GM crop segregated at the end of the process without any collection strategy.

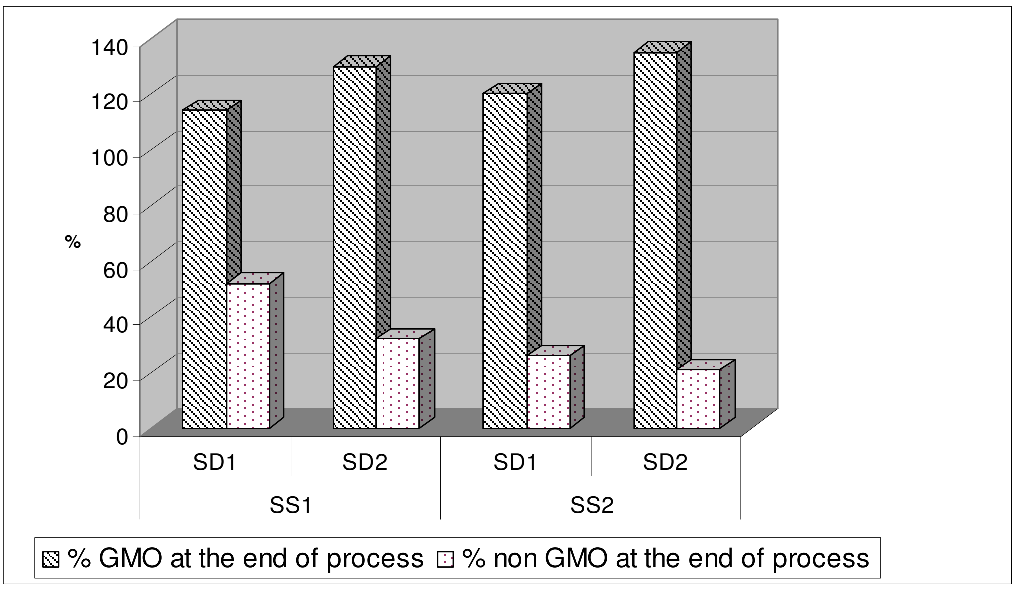


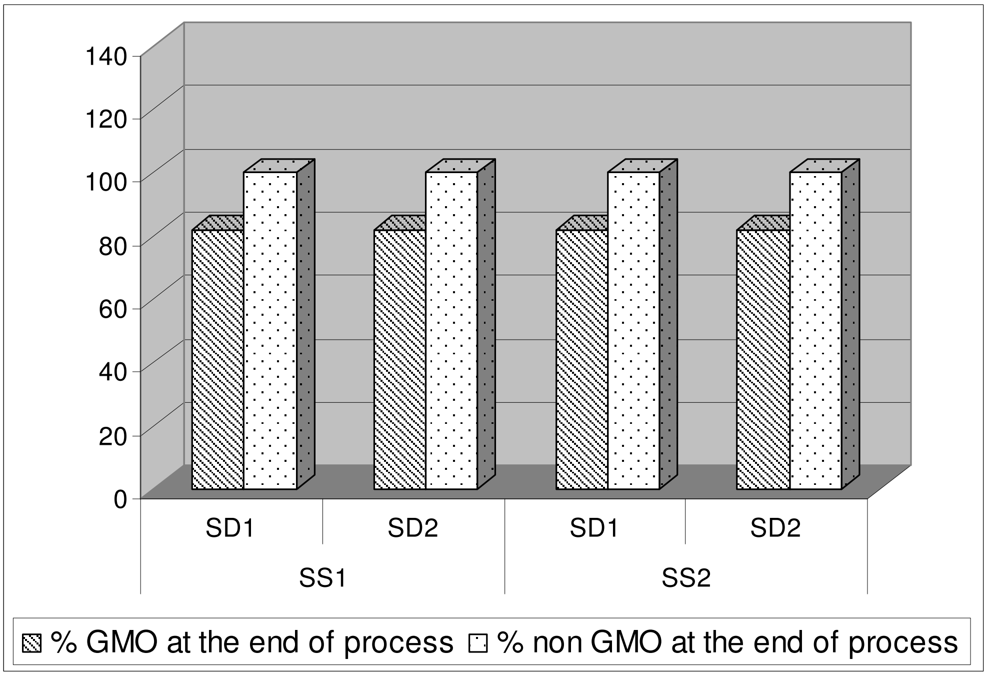
Table 2: Transport cost increase and dryer use rate for each collection strategy and for the different scheduling rules. (1) : SS1 x SD1. (2) SS1 x SD2. (3) SS2 x SD1. (4) SS2 x SD2

	No collection strategy	Collection with a spatial strategy	Collection with a time strategy
Transport cost increase	0^1 0^2 0^3 0^4	611^1 611^2 611^3 611^4	400^1 390^2 400^3 390^4
Dryer use rate	93^1 100^2 88^3 96^4	88^1 88^2 88^3 88^4	90^1 90^2 90^3 90^4

Collection with a Spatial Strategy

In this case two different supply chains are made. One third of the collection silos are allocated to non-GM products and the two other thirds are used for GM. GM and non-GM are dried into two different dryers. Figure 4 shows the ratio of GM to non-GM at the end of the collection process. The ratio of non-GM at the end of the process is nearly 100%. But the ratio of GM is low (82%). This is due to the small size of the GM supply chain compare to the size of the GM collection This come form the fact that there is only one dryer allocated to GM. It is therefore not possible to dry all the GM maize collected. Conversely the size of the non-GM supply chain is greater than the non-GM collection. So, the dryer is used below its capacity. This is confirmed by a low rate for dryer use (88%) and hence a high drying cost. Moreover, this strategy has a high transport cost which is increased by 610%. This is because it is impossible to minimise the distance between collection silos and dryers, as each dryer is allocated to one product.

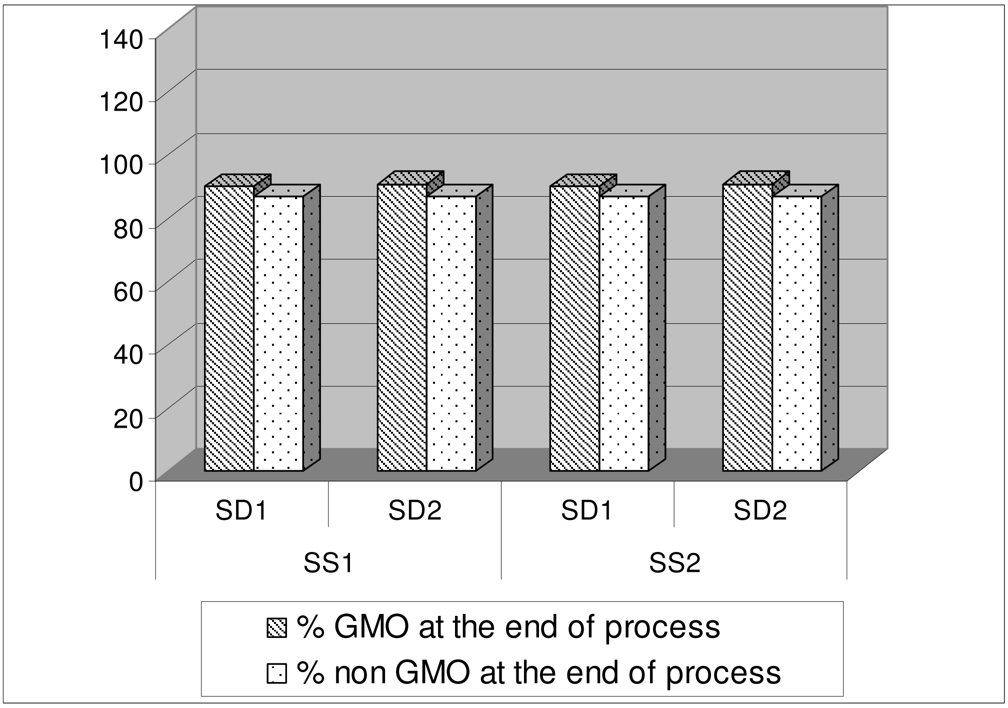
Figure 4: Rate of GM and non-GM segregated at the end of process with a spatial strategy collection.



Collection with a Time Strategy

In this case, the non-GM crop is collected in the first month of the collection period and refused after that. GM crops are collected in the last two months of the collection period and refused before then. The ratio of non-GM at the end of the process is 87% and that of GM is 90% (figure 5). Moreover, production costs are lower than for the spatial strategy. The dryers are used at 90% of their capacity and the transport cost has increased by 400% compared with a situation without segregation. These results show that segregation is done at the expense of overall collection efficacy, as not all the maize collected is dried. It is obvious in the case of a time strategy as it is impossible to dry both the whole GM and non-GM crop collected. So these strategies could lead to an increase in the duration of collection in order to dry all the maize. This will lead to a loss of quality and thus to a decrease in the prices paid to farmers.

Figure 5: Ratio of GM and non-GM segregated at the end of the process with a time strategy collection.



Conclusion / Discussion

This modelling work shows that use of decentralised scheduling rules over the course of time is less efficient than centralised decisions based on forecasting if the efficiency is judged by the quality of production (Li and Liu 2006). But we show that changing the efficiency criterion, in this case taking the production cost into account, changes this judgement. There is a choice to be made between centralised and decentralised planning and scheduling on the basis of the choice of an efficiency criterion. This decision must be made taking into account the type of market sought.

Thus there are difficulties for co-existence between GM and non-GM production at the collection level. To overcome these difficulties it is necessary to plan the collection before the collection period in order to specialize the infrastructure for one or the other product. Doing so leads to an increase in the collection cost and a decrease in the quantity of maize dried in the time required to produce the higher quality wanted by the market. A spatial specialisation of the infrastructure allows most of the collected crop to be dried, but at a higher cost. Conversely, a specialisation of the infrastructure on a time basis, with GM at the end of the collection period, minimises the cost but with a decrease in the quantities dried. It is therefore necessary to seek an optimal collection plan, taking into account the cost and the quantity dried and segregated. This optimisation could focus on the optimal collection duration of each product and on the period when each product should be collected. A combination of the two strategies with spatial segregation in a specific period could be explored.

Moreover, such collection strategies lead to the possibility of stricter collection territory governance, as considered by Byrne and Fromherz (2003). It would not be possible to introduce such collection strategies without consultation with the farmers; otherwise there is a risk that farmers will change their relationships with collection firms and sell their harvest to the firm with the fewest restrictions. These different types of governance should be evaluated taking into account the cost to the farmers and for the collection firms, together with the ratio of maize segregated.

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