Executive summary

Freedom of choice between genetically modified (GM) and non-GM products is a central goal of the EU's Common Agricultural Policy. It is essentially based on the principle of coexistence. EU Member States apply coexistence measures such as minimum distances between fields with, and without, GM that allow the growing of GM and non-GM crops in the same area, transport and market them side by side, preserving their identity in accordance with the relevant labelling rules and purity standards. PRICE researchers have studied how implementable and costly these strategies are for farmers, agri-food supply chain operators and consumers.[1] The major finding is that the current measures implemented to ensure coexistence of GM and non-GM crops in the EU are practically feasible, both at farm level and along the supply chain. However, these measures come with additional costs, which are partly paid by consumers and other supply chain stakeholders.

The PRICE results show that various technical measures are efficient to ensure compliance with the official 0.9% threshold in diverse maize agricultural systems across Europe. Within the project two years of field trials with GM maize in Spain, applying buffer zones and/or different sowing dates resulting in asynchrony in flowering have been carried out. The results demonstrated that these are effective methods for Spanish maize growers to ensure coexistence in the frame of present legislation, also at the level of small plots. Field trials with non-pollinating cytoplasmic male sterile maize in Germany, the Czech Republic and Spain showed that this is an effective biological measure. PRICE also asked 1,473 farmers in Germany, Spain, Portugal and the UK what they think about implementing coexistence measures. Both farmers growing GM maize and those growing non-GM maize told us they consider the application of buffer zones and keeping data for 5 years practical. They had more problems with applying different sowing times and the issue of liability for damage.

PRICE developed a prototype of a web-based Decision Support Tool (DST) for decision-makers (e.g. farmers, advisers, cooperatives, policy-makers). This DST enables to account for factors affecting adventitious presence, such as climate, predominant wind direction, landscape patterns, and agronomic characteristics (flowering dates). For maize, the platform allows to predict the distribution of adventitious presence of GM material in non-GM maize fields. The tool calculates the probability of a certain level of cross-pollination between GM and non-GM fields and what the expected effect is of a specific buffer zone or a difference in flowering time. The results confirm the outcomes of the EU-funded project SIGMEA (http://www6.inra.fr/sigmea, scientific coordination by INRA) and complement them in terms of adventitious presence prediction. Indeed, PRICE partner INRA has designed an innovative Bayesian-based statistical approach to predict not only the average value of adventitious presence but also the variability at the plant level. This additional step has made it possible to set up more efficient sampling strategies.

A survey among stakeholders in the maize and soy supply chain in Germany, Italy, Portugal and Switzerland shows that the vast majority of imported soybean for the feed industry is already GM but there is also a market for non-GM products. Separate non-GM supply chains that allow for non-GM products, such as "Ohne Gentechnik" labelled milk in Germany, do exist, but these are niche markets. Such non-GM products are usually integrated in a wider marketing strategy that focuses on 'organic' or refers to a specific traditional or regional origin. In general, retailers or food processors are the leading actors promoting the definitions of voluntary non-GM standards and coordinating the other stakeholders. Once the segregated supply chain is established and running, its operation becomes routine. Feed processing is a critical point for the risk of adventitious presence. A widespread solution sees compound feed processors using dedicated factories (non-GM or combined with

[1] PRICE stands for "PRactical Implementation of Coexistence in Europe". It is the acronym for a research project supported from the European Commission Framework Program 7.

organic) to ensure compliance with regulations. However, large dedicated non-GM factories often work under capacity and are unable to leverage economies of scale.

PRICE has found that coexistence of GM and non-GM products in Europe is possible under current EU legislation. The availability of non-GM soybean in third Countries, the non-GM price premium, the segregation costs along the supply chain, and the willingness to pay of EU consumers for the non-GM attribute are crucial factors for the economic sustainability of non-GM voluntary standards in the long run. Lower thresholds or other stricter measures would cause difficulties for the supply of non-GM food and feed products.

Project context and objectives summary

Coexistence of GM and non-GM production systems and food chains is still a controversial topic within the EU. Member States, farmers, and participants within the food chain have expressed an interest on the implications of different coexistence polices on feasibility and costs of achieving segregated supply chains, as well as implications for labelling and traceability. While a number of issues have already been addressed in previous projects, information about feasible and cost-effective coexistence measures at farm and supply chain level was missing. PRICE has therefore investigated the efficiency and cost of coexistence practices in a number of Member States including the innovative solutions chosen by farmers to reduce coexistence compliance costs.

Previous projects such as SIGMEA, Co-Extra and TRANSCONTAINER had a strong technical orientation and provided important information about technical options to control pollen flow for regulatory policies as part of coexistence policies. Although economic issues have been addressed within the three projects, a coherent approach analyzing coexistence practices among farmers planting Bt maize (the only widely grown GM crop in the EU) is missing. This is important as the study by Demont et al. (2008) shows mandatory requirements can substantially reduce adoption and discriminate against smaller farms (see also Beckmann et al. (2010)) while a case study Skevas et al. (2010) for Portugal illustrates coexistence requirements may not necessarily result in high coexistence compliance costs as farmers through organizational innovations can easily adapt and the degree of adoption may be affected less. Nevertheless, efficient strategies will be case dependent as adventitious presence at field level depend on a number of local factors such as landscape, micro climatic conditions, concentration and distribution of GM crop, non-GM crop and organic crop production in the region (Ceddia et al., 2009). Tools supporting farmers, local traders, competent agencies including environmental agencies and other stakeholders having an interest in achieving coexistence can help to identify efficient coexistence strategies which can lower agriculture production costs, contribute to an easier achievement of regional environmental protection goals , and support successful segregation in the supply chain. One important tool for biological containment within maize is the use of cytoplasmic male sterile (CMS) varieties, which may solve coexistence issues within maize production (Hüsken et al., 2010).

While coexistence is mainly an issue at field and farm level, issues within the supply chain also arise such as providing non-GM feed for meat and dairy products affecting farmers as well other actors in the chain. In the case of non-GM products, in order to protect reputation, one of the most valuable assets, companies want to build a more secure and traceable supply chain, based on solid partnerships and contractual relations. This vertical coordination is likely to influence the structure and the governance of the supply chain with implications on its performance and on the decisions of the actors involved.

The strategic objective of PRICE is:

Support the coherent development and implementation of crop specific coexistence strategies by identifying feasible and cost-effective coexistence measures for food/feed GM, non-food/feed GM and non-GM crops.

To tackle this objective a multi-disciplinary team has been working together on the following specific objectives:

1. Economic analysis of coexistence practices in the EU.
2. Assessing the potential of biological and physical containment methods and CMS maize in particular for achieving coexistence.
3. Developing a decision-tool software for providing information about efficient coexistence strategies at field and regional level.
4. Assessing the economic potential for new food/feed and non-food/feed GM crops and feasibilities of coexistence including seeds.
5. Investigating implications of coexistence in international and EU supply chains.
6. Developing a comprehensive information system which includes stakeholders from the start and will make research results available to the Member States and other stakeholders.

Objective 1: Economic analysis of coexistence practices in the EU.

The project team carried out the economic analysis by surveying maize farmers in the Czech Republic, Germany, Portugal, Romania and Spain; countries were farmers have experience with growing Bt maize. Both GM farmers and their neighbours were surveyed. In addition the team surveyed maize, oilseed rape and sugar beet farmers in the United Kingdom asking about their expectations for GM crops and Romanian soybean farmers and their neighbours to enquire about their past experience with GM soybeans.

The overall results of the survey indicate that coexistence measures are important factors for the adoption of GM crops. The farmers indicate that liability for damages and different sowing dates are most burdensome to them. Also, when fields are small, minimum distance rules constitute a problem for the farmers. In contrast, record keeping and buffer zones are considered practical. Coordination with the neighbours gives mixed results, and is largely dependent on past experiences.

Objective 2: Assessing the potential of biological and physical containment methods and CMS maize in particular for achieving coexistence.

The potential of biological and physical containment methods were assessed with 2 years of field trials in Spain, Germany and the Czech Republic. CMS maize was tested in all three locations in different arrangements and with different mixes of CMS maize and a pollinator. In addition coexistence measures recommended by the Spanish Seed Producers' Association, buffer zones and differences in sowing date, were tested in real field conditions.

The field experiments show that CMS maize is an effective biological tool to achieve coexistence at the field level. Additionally the results show that there is no difference in yields when the pollinator is simply mixed with the CMS maize or planted in rows in between. A mix of 15% pollinator and 85% CMS maize is a sufficient quantity of pollinator. Increasing the amount of pollinator does not raise yields, whereas decreasing the amount does decrease yields.

Both the buffer zones and differences in sowing times, resulting in asynchronous flowering, are efficient measures to achieve coexistence, even in the toughest conditions with many small fields. In all cases during the two year trials in real fields the adventitious presence in neighbouring non-GM fields was below the legal 0.9% threshold.

Objective 3: Developing a decision-tool software for providing information about efficient coexistence strategies at field and regional level.

To address the third objective the models built in SIGMEA and Co-Extra were extended. The project team designed a Bayesian model that is capable of calculating the uncertainty of adventitious presence in neighbouring maize fields, taking into account the distance between fields as well as the wind direction and difference in flowering dates.

The team also built a web-based Decision Support Tool (DST). The DST includes a regulation module and Bayesian module. The regulation module shows, given a configuration of fields in a landscape, which fields are non-compliant with minimum distance rules, allowing the user (e.g. a farmer, a cooperative or a policy maker) to identify potential problems. The Bayesian module calculates the probability distributions of adventitious presence in non-GM fields given the configuration of GM and non-GM fields and displays which fields have a low and high probability of crossing the (user-set) thresholds of adventitious presence. Thus the DST provides information about the effects of minimum distance requirements, and accounts for uncertainty.

Although currently the DST has been developed for maize, the regulation module can easily be adopted for other crops. The DST has been designed such that it can interface with the public GMO register developed by the German Federal Office for Consumer Protection and Food Safety. It also has the potential to be used for other spatial agricultural problems such as the distribution of pests.

Objective 4: Assessing the economic potential for new food/feed and non-food/feed GM crops and feasibilities of coexistence including seeds.

The original goal of this objective was to assess the potential of among others the Amflora potato. However, since it was withdrawn from the European market, this was no longer relevant. The PRICE project did analyse the GM crops in the commercial and research pipeline. This research shows a large increase in the number of events, and although insect resistance and herbicide tolerance continue to dominate, other traits slowly emerge as well. However, for the largest share of these GM crops in the pipeline, applications for import into Europe have not been sought, indicating that developers do not see economic potential for these crops in Europe.

The PRICE team also analysed the potential level of adoption of Bt maize amongst farmers based on the farmers survey. The maximum level of adoption differed between countries and was very much dependent on the coexistence measures put in place. This indicates that farmers in principle are not against GM crops in general and are open to try new varieties, but only if the rules governing their use are not too burdensome.

Objective 5: Investigating implications of coexistence in international and EU supply chains.

To investigate the implications for the supply chain we first started with a description of two supply chains that are severely impacted by coexistence: maize and soybeans. The structure of the chains was investigated in four European countries (Germany, Italy, Portugal and Switzerland) and in Brazil, given its importance for European markets. After the description of the chains, we further focused on three case studies: the supply of GM-free dairy in Germany and Switzerland and GM-free maize bread in Portugal. All data was gathered from secondary data and through interviews along the supply chain. Finally the PRICE team carried out a scenario analysis with actors from the food and feed supply chain to explore the effects of coexistence for the near future.

The results of the survey of the maize and soy bean supply chain show that the supply chains are very concentrated and vertically integrated. Often a few large agribusiness companies have vertically integrated the complete or almost the complete chain up to the compound feeders and sometimes further. However, a separate less integrated chain is present in most cases as well. Usually this chain takes up a smaller part of the market. In order to deal with asynchronous approval and low-level presence the chains usually gather their major share of imports from countries that have either no GM crops, such as many European countries, or only a low number of asynchronous approved GM crops, such as Brazil and Argentina. Identity preservation (IP) of the GM and conventional crops is managed within Europe by using dedicated facilities. However, this does cause problems because they often have to work under capacity, and are unable to leverage economies of scale

The case study of "GM-free" dairy in Switzerland and Germany showed that whereas Switzerland is completely "GM-free" , in Germany this is a niche market. Switzerland faces increasing problems acquiring its Identity Preserved (IP) feed stuff, given that the largest share of soybeans is already GM. In Germany this is less of a problem because the demand is so small. "GM-free" maize bread in Portugal is a niche market, too. The production takes up a small part of total bread sales and most players along the supply chain are small. The farmers supplying the chain are "GM-free", but further downstream mills and wholesalers import maize as well. These small players (mills mostly) do not segregate GM and non-GM and do not ask for documentation. A qualitative analysis of a number of maize bread loaves showed that all of them contained GM material and a number of them were of the 0.9% labeling threshold.

In the scenario analysis the experts identified consumer perception of GMOs and regulation as critical issues for the segregation of GM and non-GM crops and the supply chains for food and feed as a whole. Based on these two variables, different scenarios were analyzed under a wide participative approach. Under stricter regulations and even more negative consumers' perception, issues such as the isolation of the EU market, the dependency from imports and potential trade disruptions, the loss of EU processing capacity in key industries (meat, oilseed crushing, compound feed) and their resilience in case of food crises emerged as possible implications. The availability of non-GM soybean in third Countries, the non-GM price premium, the segregation costs along the supply chain, and the willingness to pay of EU consumers for the non-GM attribute are crucial factors for the economic sustainability of non-GM voluntary standards in the long run.

Objective 6: Developing a comprehensive information system which includes stakeholders from the start and will make research results available to the Member States and other stakeholders.

This objective was carried out by actively involving the stakeholders from the very beginning. Fine tuning of the research was carried out through a first stakeholder workshop in Brussels on 14 November 2012 where the research designs were presented. Progress of the supply chain analysis was presented during the 2nd stakeholder workshop during the GMCC in Lisbon on 13 November 2013. The third stakeholder workshop was combined with the scenario analysis on 11 and 12 September 2014. A final workshop for all stakeholders presenting the results of the research was held in Freising on 19 February. A website (http://price-coexistence.com/) and a linked-in group were continuously updated with activities of the research. Finally four newsletters were sent to stakeholders over the course of the project and a number of film portraits giving stakeholder views were produced.

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Summary of Science & Technology results

The PRICE project consisted of 6 work packages (WPs) with work package 1 being management and work package 6 communication with stakeholders. There were four scientific work packages:

1. Economic analysis of coexistence practices in the EU (WP 2)
2. Assessment of biological and physical containment strategies (WP 3)
3. Design of decision-support tools for coexistence at farm and regional level (WP 4)
4. Coexistence within the international and EU supply chain (WP 5)

The main methodology and results of each scientific work package are presented below.

1 Economic analysis of coexistence practices in the EU (WP 2).

1.1 General introduction and methods

This work package implemented a harmonized survey under (former) Bt maize farmers and their neighbours in Germany, Portugal, Romania and Spain, under former GM soybean farmers in Romania and under maize, sugar beet and oil seed rape farmers in the United Kingdom (UK). In addition a small case study with similar questions was carried out in the Czech Republic under Bt maize farmers.

The harmonized survey contained the following sections:

- Farmer characteristics
- Network of the farmer
- Attitudes towards the future of agriculture and the role of the government
- Attitudes towards GM crops
- Burden of coexistence measures
- Choice experiment with coexistence measures

The harmonized surveys were adapted to country-specific circumstances, e.g. in terms of coexistence measures in place, the studied crops or regarding the cultivation period. The coexistence measures studied in the choice experiment were the same for all countries: three levels of liability: never, only when non-compliant with ex-ante measures or always; three levels of isolation distances: none, 50 meters or 100 meters; three levels of information provision: none, to neighbours only or to a public register and three levels of temporal separation: no separation, 2 weeks difference with non-GM neighbours or 4 weeks difference. The survey was face-to-face in all countries except in the UK where a mail survey was used. The final sample sizes were as follows:

- Germany: 27 former Bt maize farmers, 20 conventional.
- Portugal: 29 Bt maize farmers, 27 conventional.
- Romania: 5 Bt maize farmers, 76 conventional, 42 former GM soybean farmer, 17 conventional.

- Spain: 479 Bt farmers, 291 conventional farmers and 245 farmers cultivating both.
- United Kingdom: 53 maize farmers, 96 oilseed rape farmers, 65 sugar beet farmers.

The case study in the Czech Republic covered 10 farmers.

1.2 Results for Germany

The sample in Germany is not representative for the average German farmer. Farm size is much larger than the population average, but it is representative of the early adopters, and roughly representative for farm companies in the federal states under consideration. These states are also the place where the pressure of the European corn borer is highest, making them to the most likely place to adopt Bt maize.

There were no significant differences in farm characteristics within the sample between former Bt maize farmers and their neighbours. The attitudes towards GM crops were different between these two groups, although their opinions usually went in the same direction, i.e., both would for example agree on a statement, but the agreement would be stronger in one group than in the other. As expected Bt maize farmers were usually more positive about GM crops. The main reasons for the conventional farmers not to grow Bt maize were societal and to some extent and expected difficulty in selling the crop.

In terms of coexistence measures the farmers considered full liability, requesting permission from the government and having to wait two years with sowing conventional maize on a former GM maize field as most burdensome. Keeping records for five years and checking for volunteers were considered less burdensome. The results of the choice experiment are similar. Of the tested coexistence measures full liability was by far the most disliked coexistence measure. Temporal separation was also disliked, but because of the German climate such a coexistence measure is not effective anyway. It was kept in the choice experiment to make the experiment comparable between countries. Relatively speaking, farmers seem to have fewer problems with informing their neighbours or the general public.

1.3 Results for Portugal

The sample in Portugal covered roughly 10% of the Bt growers in the country divided over all maize growing areas. The final sample of conventional farmers was of similar size. The two groups are roughly similar in composition except that the Bt farmers have on average larger farms, and correspondingly larger areas of maize cultivation. Also, the Bt farmers claimed more often to be constrained by pests and weeds whereas conventional farmers were more constrained by soil quality and climate.

Portugal is one of the few countries in the EU where coexistence at farm level is actually practiced. Apart from a number of coexistence measures farmers in Portugal have the possibility to form production zones, in which all cultivated maize is either GM or a mix of conventional and GM but intended to be sold as GM. Farmers are also flexible in the sense that they can use isolation distances, or buffer zones or differences in sowing dates. The Bt farmers ranked getting authorization from neighbours as most burdensome, closely followed by authorization from the government. Both are hypothetical coexistence measures as farmers only have to inform neighbours and authorities, but do not need their permission. Also considered burdensome were liability, 20 days of sowing difference and a difference of 2 FAO classes in the maize varieties used. The compulsory training course and record keeping were considered least burdensome. The burden of full liability and sowing difference also showed up in the choice experiment, with these measures constituting the larger coexistence costs. Isolation distances and informing the government or the neighbours seemed not to matter too much.

1.4 Results for Romania

The sample in Romania is not representative for the average Romanian farmer. Both for soybeans and for maize farmers the farm size is much larger than the population average. Similarly most farmers in the sample have a high level of education: 71% of the soybean farmers and 65% of the maize farmers have a degree of an agricultural university. The sample is, however, representative of the adopters. The HT soybean technology and Bt maize technology are mainly interesting for these large farms. This is also clear from the adoption numbers: in 2013 there were only 3 farms that produced Bt maize. HT soybean, when it was still allowed, was more popular. Production of GM soybeans doubled in hectares from 2004 to 2005. The production of soybeans almost quadrupled in the period 2001 to 2006. However, as HT soybean was outlawed when Romania joined the EU, production fell in 2007 by 60%. After that, it first dwindled, but in recent years has recovered somewhat.

Most interviewed soybean farmers do not think that coexistence measures would be a large burden to them if HT soybean was to be reintroduced. We considered the following coexistence measures: five year keeping of records, informing the neighbour, cleaning the seed drill, planting a buffer zone, and planning the sowing such that it does not coincide with neighbours. Most of these measures were ranked as relatively easy, with the exception of cleaning the seed drill, which was ranked as intermediate. The maize farmers found the questions difficult to answer or did not want to answer at all. From the five Bt producers there were only three replies to the questions about the burden of coexistence measures. One farmer considered all measures easy, one farmer considered everything easy except keeping the sowing distance, and one farmer found all measures either intermediate or very burdensome. The conventional producers were only asked about the coexistence measures that concerned them, i.e., agreeing on the sowing date, and the fact that they had to be informed by their neighbours. They ranked these measures as easy to them.

In Romania the coexistence measures seem not too hard to implement according to the farmers. What has to be kept in mind, though, is that the farms in the sample are large. This makes them relatively flexible when it comes to implementing coexistence measures.

1.5 Results for Spain

The sample in Spain was representative for the population. Although the goal was to have Bt maize growers and conventional neighbours in equal proportions in the sample this proved difficult because of the high adoption of Bt maize in certain regions of Spain. The adoption of Bt maize in Catalunia for example was 93% in 2012. The final proportion in the sample was 71% Bt maize farmers and 29% conventional farmers. The farmers were on average 55 years old, and very heterogeneous in income and education level. The Bt farmers have on average larger farms than their conventional neighbours. In addition they own a larger share of their land. As expected Bt maize growers treat their crops less frequent with insecticides. Interestingly, farmers that cultivate both also use less insecticide. Finally Bt farmers have a higher yield and get a higher price for their crop.

In Spain we asked for the burden of the following coexistence measures: sowing difference, a buffer zone of 12 rows, cleaning the sowing machine, informing the neighbours and keeping records for five years. From these measures Bt maize farmers found the sowing difference by far the hardest to implement. Buffer zones were also difficult, but less hard than the sowing difference. In comparison informing the neighbours, cleaning the sowing machine and record keeping were considered relatively easy. In Spain we made further inquiries about the conversation with the neighbour. Most farmers indicated that this was a very pleasant conversation. The results of the choice experiment confirm this; in contrast to the other coexistence measures farmers in Spain actually consider the coexistence measure of informing the neighbours a benefit rather than a cost. The choice experiment results also confirmed the results about liability and sowing differences from Germany and Portugal: they are the heaviest coexistence measure. In contrast to other countries farmers in Spain also consider implementing isolation distances very costly. This is probably because the average farm size in the Spanish sample is smaller than in the other countries, making this a more difficult measure to implement.

There is currently no official coexistence legislation in Spain, although the seed producer association prints a code of good agricultural practice on each bag of GM seed sold. This code suggests a few coexistence measures. Within the sample there were only three Bt farmers (<0.4%) that had had problems of adventitious presence in the past, and only one that had paid compensation. This seems to suggest that coexistence is functioning, at least within the sample.

1.6 Results for the United Kingdom

The sample in the UK was not completely representative of for the average farm population. The farmers in the sample where on average somewhat younger and, compared with the average of similar farm types, had a lower income. Farms were also larger than the general average, and the farmers cultivated larger areas of oil seed rape and sugar beet than the national average.

From the maize growers roughly 50% would consider growing GM maize if it was available, whereas for oil seed rape and sugar beet these percentages were 62% and 63%, respectively. Testing for differences between potential adopters and rejecters we found a number of distinct differences in farm characteristics. To summarise, the potential adopters had less years in farming, were younger, had a higher annual farm income, had larger farms, more staff numbers, were more likely to be a member of a Farmers' Union or Certification Body and were more likely to have a degree than the potential rejecters of growing GM crops. When asked why farmers rejected the crop the main reason picked was that they grew under standards that did not allow GM crops (e.g. organic). Other important grounds for oil seed rape and sugar beet farmers were that they do not believe in the potential of GM crops, or simply preferred not to change crop types. Maize farmers were on overage more positive about GM crops than oil seed rape and sugar beet farmers.

We asked about the following coexistence measures in the UK: 5 year record keeping, asking neighbours about plans, cleaning the drill after seeding GM, planting a 12 row buffer zone and a sowing difference. The sowing difference came out as the most burdensome measure, ranking 4 on a scale of 1 to 5 with 1 being very easy and 5 very hard. Buffer rows were second in line but were already considered to be neutral in burden. The easiest measure was the record keeping. The results from the choice experiment confirmed the difficulty with the sowing difference, but what came out as the largest costs was liability.

1.7 Results from the Czech Republic

The case study in the Czech Republic consists of roughly 10 very large farms that cultivate GM maize. Most farms are mixed, growing cereals and oil seeds and have livestock. The farmers are well incorporated into networks, being members of cooperatives, agrarian societies, and farmers associations. The considered coexistence measures were 5 year record keeping, asking neighbours about plans, cleaning the drill after seeding GM, planting a 12 row buffer zone, an isolation distance of 70 meters from conventional fields and 200 meters from organic fields and a sowing difference. Of these the sowing difference was ranked as the highest burden, being in between neutral and hard. All other measures were considered easy. Again, these results are in part driven by the fact that these are very large farms, making them more flexible when it comes to implementing coexistence measures.

1.8 Overall results

The general picture that emerges from the surveys is that coexistence measures are very differently ranked, but that farmers in Europe agree on a number of coexistence measures being relatively easy and others being difficult. Liability and sowing differences are mostly seen as problematic by the farmers, even in countries where sowing differences would be an efficacious measure for coexistence. When farms are small, isolation distances are a problem, too. Buffer rows are seen as an intermediate solution, being neither hard nor easy. Easy measures are record keeping and informing, but not getting authorization of the neighbours.

2 Assessment of biological and physical containment strategies (WP 3)

2.1 General introduction and methods

The PRICE team assessed biological and physical containment strategies through a combination of field trials, trials in real agronomic circumstances and literature research. The biological coexistence measure under study was Cytoplasmic Male Sterile (CMS) maize; the physical containment strategies were sowing differences, buffer zones and isolation distances. In addition pollen traps and quick methods for determining the amount of GM pollen in the air were tested.

The efficacy and yield of CMS maize was tested during 2 years of field trials in Spain, Germany and the Czech Republic. CMS maize is sterile and therefore produces no pollen, and hence needs to be planted combined with a pollinator. Thus in the field trials different mixtures of pollinator and CMS maize were combined in different arrangements: planting in rows or mixed. The effect of different pollinator varieties was also tested. Finally previous research has shown that CMS is not a completely stable trait. Therefore we tested its stability under various circumstances, and its outcrossing with nearby fields.

In Spain the coexistence measures recommended as good agricultural practice by the seed association were tested under real agronomic conditions. The team conducted two years of trials with buffer zones and sowing differences. We predicted the adventitious presence in neighbouring non-GM fields with a simple model, and tested the actual adventitious presence through PCR analysis. The further efficacy of CMS maize for achieving coexistence and other measures was investigated with literature research.

The pollen traps were set-up at the field trials in Spain. Their content was analysed with conventional as well as newly developed methods.

2.2 Results CMS maize

Over two years, in all countries there were no differences in yield between fields where pollinators were sown in rows between the CMS maize and fields where the CMS maize and the pollinator were simply mixed in the seed tank. Also, there were no significant differences between mixtures of 15% pollinator, and mixtures with 20% pollinator. Yields did decrease significantly, however, when only 10% pollinators were used.

In the row arrangements the pollinator and CMS maize were harvested separately. From these harvests it became clear that the harvest of the pollinator was consistently lower than that of the CMS maize. This could affect the results because a relatively higher amount of pollinator in the mixture would reduce the overall yield. Therefore in the third year we used the same arrangements, but a different pollinator, as well as a comparison plot with the original pollinator. The results of the previous two years were confirmed in these trials, but in addition the total yield was significantly higher than the comparison plot. This difference in yield disappeared, however, when the pollinator yield was excluded. In summary, these third year trials confirm our results from the first two years. For cultivation the current recommendation for this system is to use 20% pollinator, but our results show that this can be decreased to 15%.

Previous research had already shown that the male sterility of CMS maize is not completely stable. Depending on climatic conditions, fertility can be partly restored. The fertility of CMS maize was thus tested at different levels of air temperature and soil moisture in greenhouses. The results show that the CMS trait is stable at high temperatures, but becomes partly fertile at lower temperatures. There was no effect of soil moisture. This restorative effect is, however, dependent on the variety and genotype. In order to test the potential effect on coexistence the outcrossing potential of CMS maize was tested in field experiments in Germany, the Czech Republic and Spain. The outcrossing potential of the CMS maize was minimal in all cases tested. Outcrossing was highest in the first few rows, and decreased rapidly afterwards. An isolation distance of 10 m was sufficient to reduce the adventitious presence far below the 0.9% threshold.

2.3 Results of coexistence measures in real agronomic conditions

A survey of the literature has shown that the physical factors controlling cross-pollination are mainly climate and location, with prevailing wind direction and strength determining the pollen transport distance. Also important is the size of the field: larger fields emit more pollen. Finally since outcrossing only takes place in the first few rows, it may be worthwhile to work with buffer zones which are harvested separately, or isolation distances.

The two year trials in Spain under real agronomic conditions show that the coexistence measures suggested by the association of seed producers work well in all cases. We tested the measures in the worst-case scenario for coexistence: many and small-scale fields. Each year coexistence measures were implemented in three clusters of fields. The tested coexistence measures were buffer zones of 12 meters, corresponding to 9 rows of maize, and asynchronous flowering achieved through implementing sowing differences of four weeks in April, or two in May. In 2012 we tested three clusters with buffer zones; in 2013 we tested one cluster with buffer zones and two with asynchronous flowering. The results are shown inTable 1. As can be seen in all cases the adventitious presence was below the 0.9% threshold.

Table 1: Adventitious presence in neighbouring fields

% MON810					
Season	**Site**	**Conventional field size (ha)**	**Coexistence strategy**	**Experimental GMO% (qPCR)***	**Predicted GMO% (GIMI 2.0)**
2012	**1**	0.40	buffer zone	0.23	-
	2	0.50	buffer zone	0.41	0.26
	3	0.41	buffer zone	0.33	0.29
2013	**S1**	0.47	buffer zone	0.12	0.34
	S2A	0.24	flowering asynchrony	0.07	0.88
	S2B	1.00	flowering asynchrony	0.01[1]	0.00

We also tested the predictive capability of the GIMI 2.0 tool. Its predictions fitted the results of 2012, but not in 2013. The reason is probably that an unusual strong hail storm took place in 2013 when the maize flowered, reducing the amount of pollen.

2.4 Pollen traps

In order to assess the amount of GM pollen in the air pollen traps were placed in Spain for two consecutive years. However, assessing the pollen cloud from the samples taken from pollen traps faces two major problems: a limited amount DNA is available and the samples contain PCR inhibitors. The PRICE team developed and tested two methods capable of detecting multiple traits of GM pollen: 1) combining whole gene amplification with pre-spotted plates; 2) a system using dynamic arrays. Both methods look promising but need further validation.

2.5 Overall results and conclusions

Our results suggest that CMS maize is a useful tool for coexistence purposes. However, the trait should be carefully selected based on its purpose and intended environment because the different varieties exhibit different amounts of sterility depending on air temperature. Moreover, the pollinator should be carefully selected as it has an important effect on yields. Our results also show that a mixture of 15% pollinator is sufficient to reach the maximum yield, and that it is not important whether the mixing is achieved through planting row by row, or simply mixing in the seed tank.

The results of the field trials show that coexistence is possible for maize in real agronomic conditions, and that farmers can equally choose between buffer zones or differences in sowing date. Both measures result in out-crossing below the legal thresholds.

Finally we have developed two promising methods to assess the composition of the pollen cloud.

3 Design of decision-support tools for coexistence at farm and regional level (WP 4)

3.1 General introduction and methods

We focussed on several decision-support tools structured around earlier developed gene-flow models, and their potential use. The gene-flow models developed in the earlier EU projects Co-Extra and Sigmea were used as a starting point. From there the team:

1. Further extended the original model to include uncertainty and confidence intervals
2. Used the gene-flow model to design and test better sampling strategies
3. Developed a web-based decision-support tool to assess potential outcrossing problems in the field

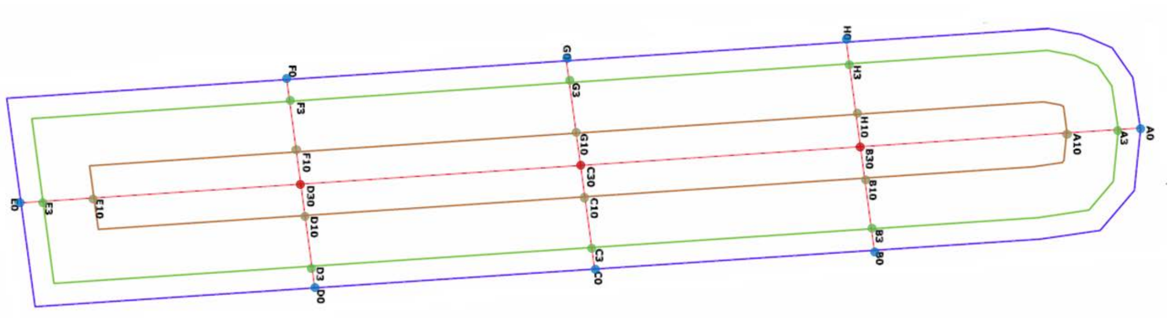
3.2 Development of Bayesian models

The models developed within Co-Extra and Sigmea are deterministic gene-flow models, i.e. their output consists of a single value of adventitious presence per field given a number of input variables such as landscape, distances between fields, wind direction et cetera. Many of these factors, however, are uncertain. The team developed a number of Bayesian models in which all input variables are considered to be stochastic rather than certain. The main factors considered were: distance, wind speed and direction, and flowering asynchronicity. These factors were included in three different dispersal functions, describing the probability that pollen emitted at a certain location fertilizes an ovule at another location. These dispersal functions are then integrated over space, combined with the location of non-GM and GM plants to calculate the overall adventitious presence. We tested several models consisting of different combinations of dispersal functions and different underlying distributions.

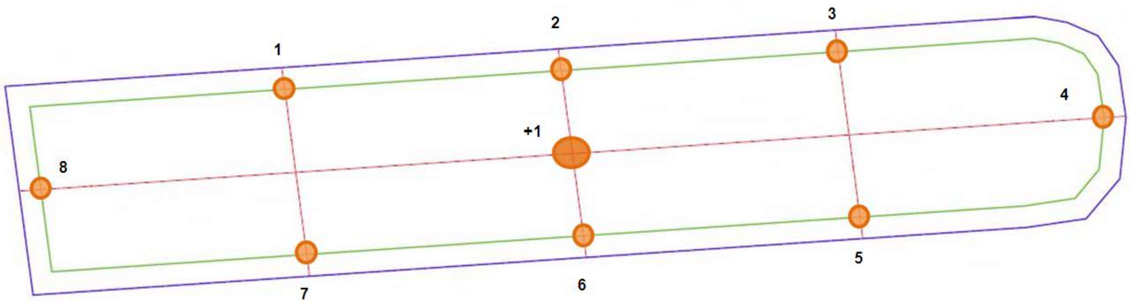
The outcomes of the models are probability distributions per field indicating the probability that a field will cross a user-defined adventitious presence threshold. The width of the probability distribution, that is, the uncertainty is reduced if more data is available. The models have been calibrated and perform well, when a single source field is used. We also tested the models in the case of landscapes with multiple sources. However, it turned out to be impossible to calibrate the models if multiple sources are used. Therefore we opted to test the predictions of the models calibrated on single source datasets in a multi-source landscape. Unfortunately, in this case the model performance is poor; it does, however, reproduce the ranking in terms of adventitious presence.

3.3 Using gene-flow models to optimize sampling strategies

In order to determine adventitious presence at field level, several samples have to be taken within the field, and the samples have to be analysed with Polymerase Chain Reaction (PCR). A standard stratified sampling procedure typically requires 27-28 samples, all of which have to be analyzed with PCR. We tested a simplified approach, which takes 9 samples, of which 8 are mixed into a single sample, resulting in a required number of 2 PCR analyses. Figure 1 shows both sampling schemes. Both sampling schemes were tested in real agronomic conditions in several fields over two years. Further validation was carried out with existing datasets. The two sampling methods did not produce significantly different results, indicating that the simplified approach is an adequate replacement for the standard approach.



Standard Approach



Simplified approach

Figure 1: Standard and Simplified sampling approach. Sample places are marked with dots.

As another alternative to the standard stratified approach we tested the possibility to let sample location and number be guided by the predictions of a gene-flow model. Using outcrossing datasets with known probability of adventitious presence we ran simulations to find the number of samples required for different sampling methods to correctly quantify the level of adventitious presence. The sampling methods tested were simple random sampling, stratified sampling with five strata, stratified sampling with 50 strata, and two methods using the output of the gene-flow model. The two methods using the gene-flow model outperformed random sampling, and often stratified sampling as well in terms of correctly predicting the level of adventitious presence.

The outputs of the model can also be used to update calculations of adventitious presence after sampling has taken place. When stratified sampling is used the adventitious presence in one stratum is supposed to be constant, and the overall adventitious presence is calculated as a weighted average of the strata. The gene-flow model allows a reweighting of the strata, to predict the level of adventitious presence more precisely.

3.4 Development of a web-based decision-support tool

We developed a decision-support tool (DST). The software package can be accessed via the Internet and includes two model types: the regulation model and the Bayesian model. It basically follows a number of steps (also shown in Figure 2):

1. A user logs in on the tool and defines a field configuration, either by drawing the fields by hand or using ready-defined fields based on e.g. cadastral data
2. For each field information on crop and variety, as well as GM or non-GM is entered
3. The user selects the landscape and creates a scenario.
4. Within the scenario a simulation is created by selecting either the Bayesian or regulation model, setting its parameters and running the model
5. The results are displayed at field level

6. The user then has to possibility to update the parameters and re-run the model

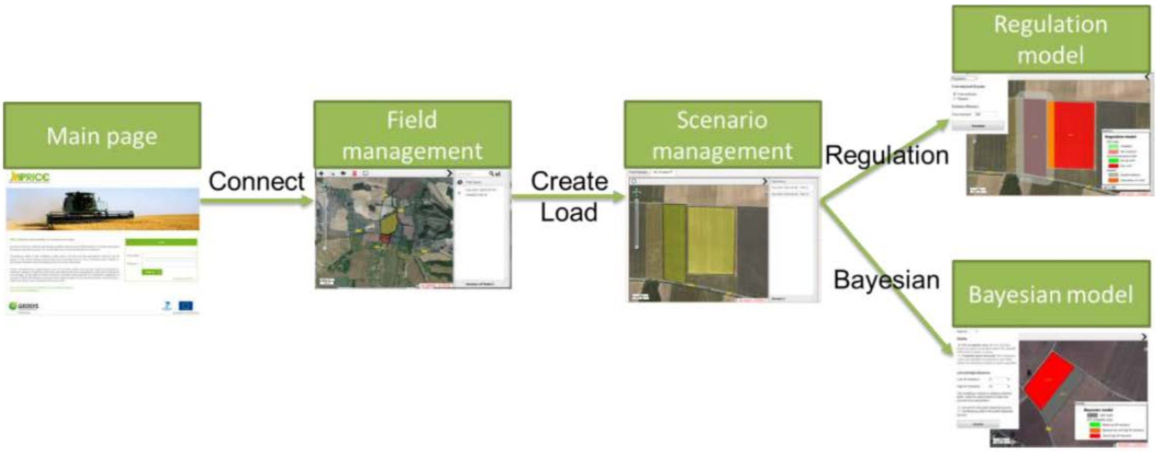
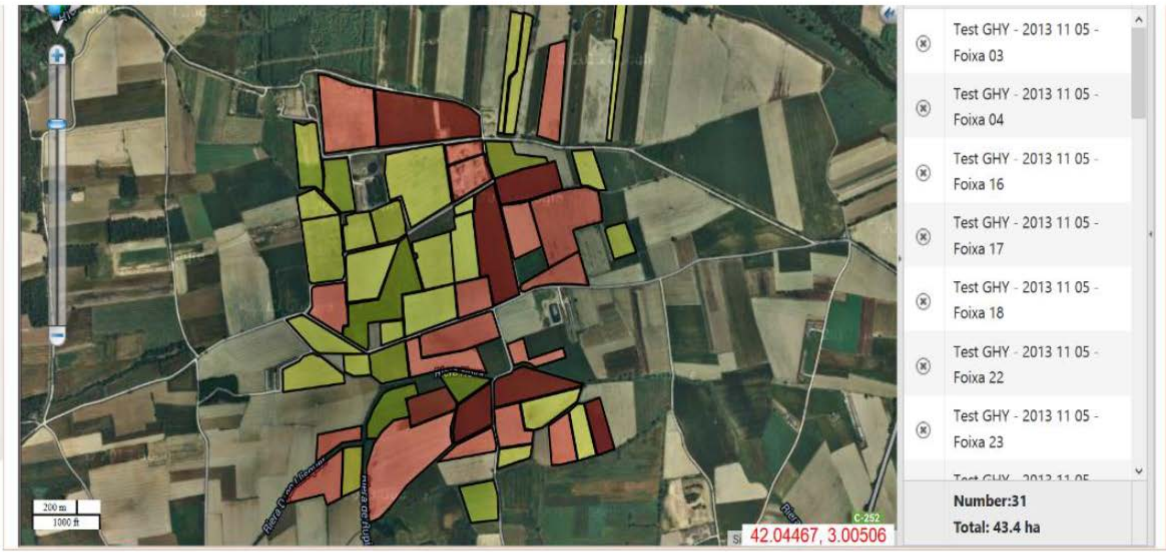


Figure 2: Flow within the Decision support tool

The regulation model considers minimum distances (set by the user). The model output displays which GM fields are compliant or non-compliant with the isolation distances given the defined landscape. The Bayesian model uses the gene-flow model described in section 3.1 to calculate probability distributions describing the probability of adventitious presence for each field. The thresholds for adventitious presence are defined by the user. The user can also indicate whether or not the Bayesian model should take wind and flowering date into account. The input data required for wind and flowering date can either be entered by the user or taken from a database. Screen shots of the DST are shown in Figure 3.



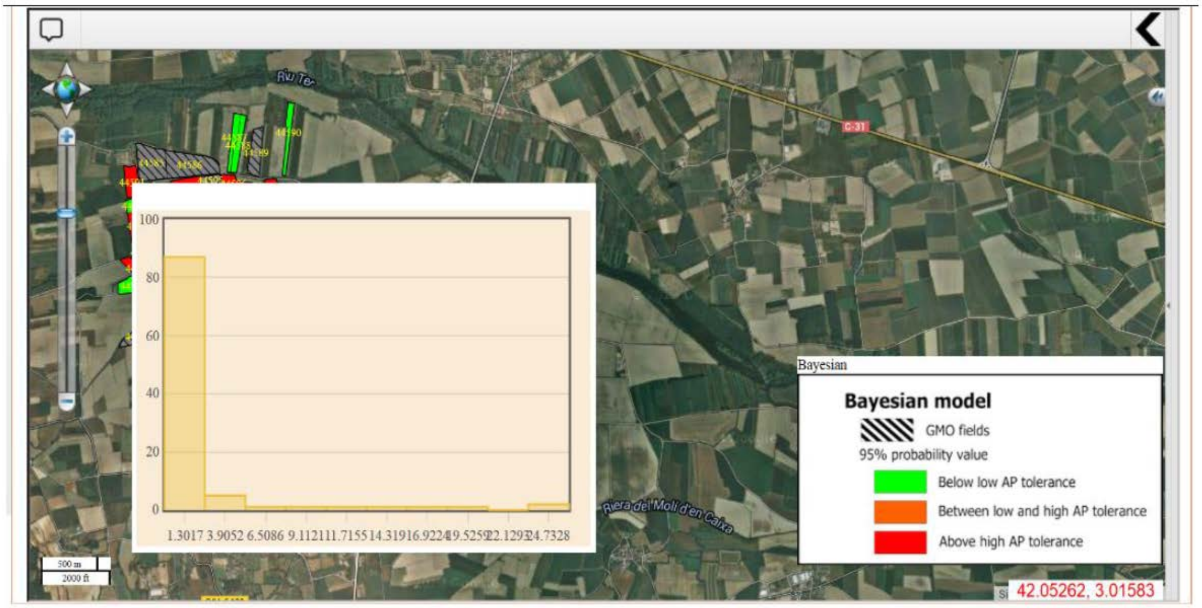


Figure 3: Screenshots of the DST

The DST has been designed such that it can interface with the public register for GM crops if one is available. As an example the DST has been linked with an interface a newly designed public register for GM crops in Germany. This register in Germany in turn has been designed such that it fits the needs of EU member states and can be easily adapted to specific local requirements.

A remark of both stakeholders and member states on the decision support system and the location register is that both are in their country not very relevant because GM crops are not currently cultivated, and this is not likely to change in the near future. They did see other potential uses for the tool, though, because it can easily be adapted for other uses such as outcrossing for the seed industry or to model the spread of diseases or pests.

3.5 Overall results and conclusions

We have developed a Bayesian model that allows us to calculate probability distributions and confidence intervals on predictions of adventitious presence, taking into account distance, wind speed and direction and differences in flowering time. This represents a major step forward in the model-based predictions of adventitious presence.

We have also shown how these model outputs can be put to good use for example in generating a sampling design, recalculating the adventitious presence in a field, or as part of a decision support tool. We expect that the optimized sampling designs will be of help in countries where coexistence is a reality.

The DST has the capability to show the devastating effects of implementing uniform isolation distances, especially if they are large. Moreover, it can be easily adapted for other uses in areas where Bayesian modelling and uncertainty play an important role, such as the spread of pests in a landscape.

4 Coexistence within the international and EU supply chain (WP 5)

4.1 General introduction and methods

Within this work package the PRICE team focussed on how coexistence is regulated and implemented further down the supply chain, i.e., beyond the farm level. In order to narrow the analysis down we decided to focus on soybeans and maize, and mainly on the supply chain towards compound feeders. We further investigated two smaller case studies: the supply of "GM-free" dairy in Germany (and to a lesser extend in Switzerland) and the supply of "GM-free" maize bread in Portugal. Finally we looked at potential issues for the regulatory framework within which the supply chains operate. The issues considered are legal complaints at the WTO and the challenges associated with asynchronous and asymmetric approval of GM crops.

We investigated the international supply chain of soybean and maize in Brazil, because it is an important trading partner of the EU. In addition we investigated the supply chains of these two commodities in Germany, Italy, Portugal and Switzerland. All investigations took place by interviewing stakeholders along the supply chain face-to-face, except for Brazil which is largely based on a literature review. In addition we used secondary data, e.g. from national statistic offices to complete the picture. The maize bread case study in Portugal is also based on face-to-face interviews, for the case study of "GM-free" milk in Germany we used a combination of postal and internet survey. The research on potential issues was mainly literature research. Finally, in order to also investigate the future of the supply chain we developed a scenario analysis together with stakeholders from the supply chain.

4.2 The supply chain of soybean and maize in Brazil

Thanks to a substantial reinforcement in yields throughout the period 1999-2011, Brazil has become the second world largest soybean producer behind Unites States. Soybean production is distributed across states, with southern and mid-western states accounting for almost 80% of the production. 2011 domestic production of soybean meal stood at roughly 28 Million Metric Tons (MMt), a 60% increase over the last decade. Brazil exported 39MMt soybeans in 2012; China was the main customer, followed by the EU. Soybean meal exports have stabilized over the last years and stood at 14 MMt in 2011; Europe is still the largest importer of Brazilian soybean meal.

Maize production in Brazil has also increased over the last few years from 42 MMT to 56 MMT in the period 2006-2010. In part it benefited from the expansion of soybean in the mid-west because it is grown in rotation with soybean. Therefore the mid-west produces the largest share of the winter maize. The South is the most important region for summer maize producing 42% of the total. Brazil is currently the third largest exporter of maize in the world. Maize exports to the European Union are relatively small, comprising 0.4 MMT to both the Netherlands and Spain.

Farm size is largely uneven across Brazil: southern farm are medium-small enterprises whereas some of the largest are located in the mid-west. In 2009, over 75% of Brazilian grains, oilseeds and meat were produced by those large-scale agricultural enterprises. Small farms are more likely to market their products and buying their inputs through cooperatives. The large farms access the international markets directly and do business with multinational grain traders. These marked differences in scale between southern and mid-western farming system are true regardless the product (maize or soybean). Corporate-like farms may be also vertically integrated into livestock production.

Oilseeds crushing capacity is unevenly spread throughout Brazil: to date, the state of Mato Grosso is the largest soybean crusher (20.7% of the daily processed volumes), followed by Paraná (20.2%) and Rio Grande do Sul. The soybean processing industry is highly concentrated: the Brazilian Oilseed Processor Association (ABIOVE) has 11 member companies, which are responsible for approximately 72% of Brazil's soybean processing capacity. Among ABIOVE members, international marketing companies are key actors along the soybean supply chain.

Since an adequate storage capacity is necessary for the supply chain to work smoothly, avoiding bottlenecks and exchanging information adequately, the lack and the inadequacy of Brazilian warehouses represent a weak point of Brazilian maize and soybean productive systems. This forces the product in the marketing channel directly after harvesting, shrinking prices and generating congestions at the terminal elevators. These limitations may preclude the supply chain's ability to capture several seasonal marketing opportunities: small farmers are often forced to sell their products at harvest time, when prices are lower, while large farms may exploit their self-financing capacity to build on-site storage waiting for better marketing conditions. This problem is more pronounced in the mid-west because the development of transportation and storage infrastructures lagged behind the crop explosion and products are moved mostly by truck. The majority of storage capacity is nowadays operated by agro-industries and international trading companies which control elevators, trucks and port terminals.

4.3 The supply chain of soybean and maize in Italy

Italy is one of the largest producers of soybean in Europe, producing over 50% the total EU 27 production. Nonetheless this production only covers 16% of Italian domestic consumption, illustrating the minor role soybean production plays in the European Union. The rest of the soybeans are imported, mainly as soybean meal, with Brazil and Argentina the as the main suppliers. Regarding maize Italy is almost self-sufficient. The imports that do take place come from EU member states that do not cultivate GM crops either (e.g. Germany, France or Hungary). Thus with regard to maize Italy does not have any problems of segregation or labeling, as there basically is no coexistence.

The structure of the supply chain for soybeans and maize is very similar. Both start at the domestic farmers and international traders, moving on via the elevators. The international traders in the soybean chain import both soybeans and soybean meal. From there the crops are processed by the mills and crushers. Subsequently this is further processed by the compound feed industry, followed by distributors, livestock producers, processors and retailers. The main difference between the supply chains is the weight of the international traders compared to the domestic producers. Given the larger share of imports in the soybean supply chain, the importance of the international traders is also increased.

Farms producing maize or soybeans are small or middle sized in Italy, often organized in cooperatives, in order to increase their bargaining power, and to mitigate risks. The farmers rely on contracts and gentlemen's agreements to deal directly with the crushers, mills and compound feeders, bypassing the elevators. The international traders in contrast have relied on mergers and acquisitions and are now concentrated in a few large companies. However, for vertical integration the companies also rely on cooperation, strategic alliances and gentlemen's agreements. The crushing industry in Italy is characterized by a few large players (the two largest firms own more than 50% of the market share according to our estimates) and many small ones, all in all roughly 40.

A difference between the maize and soybean supply chain is the downstream vertical integration with the processing industry. Whereas the crushers are not integrated with the compound feeders, the maize mills often are part of the feed industry. The compound feed industry itself is relatively fragmented, consisting of roughly 260 firms. One reason for the fragmentation is that local firms are able to exploit local niche markets. Moreover, many of the larger compound feeders are vertically integrated with the livestock industry.

4.4 The supply of soybean and maize in Portugal

The Portuguese supply chains of maize and soy depend for a large share on imports. Portugal does not cultivate soybeans so everything is imported, mainly from the United States, Brazil, Paraguay and Argentina. It does cultivate maize but not enough to cover its domestic consumption. Consequently more than 60% of the maize consumption is imported as well, mainly from Ukraine, the United States, France and Brazil. In contrast to the other European countries described here Portugal does cultivate GM maize, even though its share is minor (5.6% of the maize area in 2011). Imports of both maize and soybean are dominated by a few major traders. These companies are integrated upstream with the suppliers abroad, and sometimes downstream integrating transport services or a crusher. Products are tested when they enter the ports for non-authorized events, and in the case of "GM-free" products, for the presence of GM. Non-GM maize is mainly sourced from other European countries, and often processed at different terminals or ports in order to keep it separated. The companies deliver their products to the wholesalers, the mills in case of maize and the crushers in the case of soybeans.

Maize is cultivated and mainly delivered to farmer associations, which pass it on to the mills and wholesalers. The mills work mainly for the food industry and choose to rely on non-GM maize; the wholesalers mainly deliver to the compound feed industry and use both. The wholesalers play a crucial role in the soybean supply chain. Soybeans are imported by international traders as soybean meal which is directly delivered to the wholesalers, and as soybeans which are delivered to the wholesalers indirectly via the crushers. Soybean oil from the crushers goes to the food industry and biodiesel. The wholesalers deliver both the maize and soybeans to the compound feed industry, which provide the livestock industry with feed.

Most maize produced in Portugal goes to the feed market (94%). As the feed industry labels all their products as GM segregation is not an issue here. Most farms are small and therefore farmers organized themselves in farmer associations. These tend to own dryers and storage facilities, but the capacity is limited. The farmer associations deliver the maize to the wholesalers, although some maize goes to the mills as well. In line with the mills' focus on the food market and non-GM products they source their maize mainly from wholesalers, with minor shares coming from the farmer associations or directly from the farmers. The flour of the small mills goes mostly to bakeries. The large mills deal more often with the farmers and cooperatives directly or import maize themselves, and there is some contractual vertical integration between them and their suppliers. Their products go to large food companies, as well as national breweries. In order to keep GM and non-GM separated the large mills have dedicated plants.

Two wholesalers dominate both markets. The wholesalers and traders both supply GM and non-GM maize, but with regard to soybeans they mainly trade GM; there are only three crushers in Portugal. The compound feed industry is more diverse comprising roughly 125 companies, although the 10 largest compound feeders own 75% of the market. This is the only part of the Portuguese supply chain where vertical integration takes place on a larger scale. About 60% of the sales of the compound feeders go to downstream integrated livestock producers, and livestock processors, such as the slaughter houses and the egg industry. The compound feeders do not process IP GM free products; everything is labeled as GM. The main reason is the small demand and the fact that the world market for soybeans is dominated by GM soybeans.

4.5 The supply chain in Germany

Germany imports its soybeans mainly from the USA, Brazil and Argentina but mostly indirect. That is, soybeans enter the EU in Antwerp, Rotterdam or Amsterdam, although some imports come more directly entering at Hamburg or Brake. Soybeans are then transported to a crusher or compound feed producer elsewhere in Europe, not necessarily Germany.   The crushing facilities are often integrated into the trader and are done on import location or country of export. Maize in contrast is cultivated, and covers 50% of the German needs. The other 50% is imported, predominantly from Eastern countries: Russia, the Ukraine, Hungary, Croatia and Serbia. Whereas the maize exported by the first two enters Germany via northern ports (Rotterdam, Amsterdam, Hamburg or Brake), the latter three export their maize mainly via river.

The supply chains in Germany for maize and soybeans are similar to those in Portugal and Italy. The most important difference is the level of vertical integration and market concentration. In principle the chains start at the cooperatives, local traders and the international traders, products are elevated and distributed to crushers and mills. These deliver their products to the compound feeders that produce feed for the livestock producers. Some of the international traders, however, have their own supply chain, integrated from farmer to livestock producer and processor. Thus whereas the supply chains as described in previous chapters exists in Germany, there is an alternative supply chain that is completely integrated. Complete integration does not always mean, however, that the firms do not trade on the open market. In many cases the integrated firms treat each other as regular market partners rather than parts of the same firm.

Soybeans for the crushers are centrally bought by the international traders, in order concentrate purchases. The international traders, in which most mills and crushers are integrated, focus on GM products, especially when it comes to soybeans because the segregation is too expensive. The maize from Germany for the mills is bought mainly from farming cooperatives and agricultural traders, as farms in Germany are relatively small. A large share of the maize production goes into ethanol, the other main products from the crushing industry go to the compound feeders. The compound feeders buy their maize from domestic suppliers, mostly from agricultural traders and cooperatives. Imported maize is imported as grain, import as by-product is rare. The share of international maize is changing depending on the harvest conditions in Europe. Maize from the USA is avoided because of the asynchronous approval risks; 90-100% of the imported maize is of European origin. The internationally sourced maize is bought from national traders mainly, multinationals account for 20%. In years of exceptional scarcity maize is imported from South America. Soybeans are bought from multinationals or are bought by integrated traders. The products of the compound feed industry go mainly to cooperatives and domestic traders.

The amount of “GM-free” soybeans used by compound feeders is unclear, but estimated to have a share of 15-20%. “GM-free” soybeans come mainly from Brazil although Italy and Austria export some as well. Some smaller companies have decided to switch to “GM-free” completely, choosing to specialize on these products. The larger companies do produce both, mainly by using different plants or sometimes through flushing, cleaning and timing.

Horizontal integration has taken place at several levels. The German farmers are often organized in cooperatives, selling and buying their products together. The international traders are horizontally integrated as well; only a few exist. They have often integrated the crushing and milling activities, which do not necessarily take place in Germany. The compound feed producers too, are very concentrated, 80% of the market is in the hands of five firms, even though the German association of compound feeders has 260 members.

4.6 Supply chain of soybean and maize in Switzerland

The one major difference that sets the supply chains of Switzerland stands apart from those of other European countries is that Switzerland is in principle "GM-free". No imports of GM crops are allowed into the country at all. This means that segregation of the chains has to take place outside of the country.

Switzerland does not cultivate soybeans and consequently everything has to be imported and everything has to be "GM-free". This severely restricts the choice in nations to import from. The bulk comes from Brazil as it is the only nation that trades both GM and “GM-free” soybeans. In addition soybean products are imported from China and India, and a minor share comes from other European countries, most notably Austria, Romania and Italy. The products enter Europe in Rotterdam, and to a lesser extent Hamburg, Brake and Antwerp. They are then further shipped to Basel via the river Rhine. Maize is cultivated in Switzerland, but the share of imports relative to domestic production varies widely by year. If harvests of forage crops are good, farmers sell their maize as grain maize, but if harvests are bad they use the maize as silage, driving up imports. Imports of grain maize come mainly from France and Germany and are sourced from cooperatives and national traders.

The soybean supply chain within Switzerland is very similar to that in other European countries, but it uses only “GM-free” soybeans and derivatives. The maize supply chain on the other hand is different as it is more variable and several short supply chains exist. It is not uncommon to have linked contracts: for a farmer to be able to sell his maize to a collection point, he needs to buy his feed there. Sometimes the farmer sells the maize directly to the compound feed producer and gets the feed at a reduced price. The import market for soybean in Switzerland is very concentrated: one corporation has a market share of approximately 80% of all soy and protein imports. One reason is that the supply on the Brazilian side is also very concentrated; there are only two to three suppliers of non-GM soybean. Soybean crushing takes mainly place outside of Switzerland, sometimes in the country of cultivation, sometimes in the country where imports enter Europe (Germany and the Netherlands) and are often integrated in the multinationals or the feed industry. In contrast, the maize mills are a national business. The collection points play a central role here, elevating farmers' maize and selling it to the feed mills, although some collection points have their own feed mills as well.

The compound feeders rely on domestic maize, but its share varies, depending on the harvest. Imports come from Germany and France for conventional maize. For soybeans the bulk comes from Brazil and in recent years, increasingly from India. Compound feeders are in a concentrated market, there are 19 in Switzerland. Of these 19, five account for the lion's share of the market. As mentioned Switzerland is completely GMO free in terms of crops and therefore segregation takes place outside of Switzerland. As there is no coexistence in the country or in the supply chain, the risk of asynchronous approval is merged with the risk of importing any GM crops. However, it is increasingly difficult to get hold of "GM-free" material. The range of events to which the risks of accidental import applies is large and as such poses a threat to Switzerland. Given the ever increasing presence of GM crops, especially in soybeans the question is how long Switzerland can hold on to its "GM-free" policy.

4.7 "GM-free" dairy in Germany

At least five percent of German milk was labeled as GMO free in 2011. After the decision to run a GMO-free label is made, dairy operators usually ask feed traders to include GMO-free feedstuff in their portfolio. It was reported that these negotiations initially were not met with acceptance by the feed traders. Although it is increasingly difficult to find GMO-free soybeans on the world market, the separated GMO-free chain as such has become more or less business as usual. In addition, dairy operators inform farmers about the legal feeds available, put them under a respective contract, and hire a control company to check for compliance. The certification process has now been standardized.

Consumers demanding GMO-free milk in Germany can choose from three different systems:

a) A range of dairy products labeled as GMO free focuses particularly on the added value of the GMO-free attribute and does not differ otherwise from conventional products.
b) The most traditional solution to obtain GMO-free products: organic production.
c) Intermediate production systems. These systems aim to be more environmentally friendly and socially sound than conventional systems but more productive than organic systems.

The dairies responding to the survey can be distinguished in those marketing conventional milk, those marketing organic milk and those making use of the GMO-free segment. These three groups perceive the market opportunities in different ways. In general conventional milk producers are most negative about the "GM-free" attribute and the market associated with it, organic dairies are most positive about it and non-organic producers with a "GM-free" label tend to be in between. In the view of the dairies the high prices for "GM-free" materials and the low willingness to pay for the "GM-free" attribute constitute the main limiting factors in the production of "GM-free" milk. Again the organic producers are generally more positive about the limiting factors, that is, they consider them to be less of a limit.

4.8 "GM-free" maize bread

Maize bread is a minor but traditional bread type in Portugal, particularly in North and Centre regions where maize is grown. No formal statistics are available for this specialty, but according to one of the two largest Portuguese retailers maize bread has a 1% share in its bread business. In the feed industry labelling all production except organic, is labelled GM. The other maize destinations (starch, beer, breakfast cereals and baby food) require non GM-maize. The different firms involved in these businesses are professionally committed to apply labelling and coexistence rules and, in some instances, go even further in Identity Preservation (IP) by adopting the 0.1% threshold for the presence of GMO presence in non-GM food products. The maize bread supply chain in contrast is a pretty small and peculiar branch: in spite of a few bread factories and being present in big retail, maize bread is often the final product of small local mills and bakeries, and thus comprises an atomized market.

Maize for maize bread comes partly from farmers in Portugal and is partly imported. All interviewed farmers did not grow GM maize, nor did they have GM neighbors. Most do not certify their maize as non-GM. Most farmers deliver to wholesalers. Wholesalers work both with local and imported maize and some trade both GM maize, which goes to the feed industry and conventional maize which is used for other products. Others trade exclusively conventional maize. Most wholesalers do not ask for certification of non-GM. Mills buy their maize mainly from wholesalers, which is partly import, although some have own production or import directly from Spain. The mills sell their flour predominantly to bakers. Only 40% of the mills require certification of the absence of GM. In addition, although 60% of the mills process both GM and non-GM, roughly 70% of the interviewed mills do not segregate. Only a minority of the mills test the incoming maize or the produced maize flour for the presence of GM. Bakers buy their flour predominantly from the mills, but only a minority of them requires their flour to be "GM-free", and only a few require certification, or test the bread for the presence of GM.

As a qualitative test we bought 16 maize breads across Portugal and had them analyzed for the presence of GM material. All samples tested positive for both the GM maize event Mon810 and the event NK603. A number of them went over the labeling threshold in the case of Mon810, meaning that they should officially be labeled as GM bread.

4.9 Potential challenges over the legal framework before the World Trade Organization (WTO)

We analyzed the current legal framework, without the opt-out clause, in the light of the previous challenge of the EU legal framework before the WTO. This challenge took place in 2003 when the United States, Canada and Argentina complained about the quasi-moratorium that was in place.

The WTO at the time ruled that by the own rules of the EU there was no moratorium, but that the approval of several GM products had been "unduely delayed". They also ruled that the cultivation bans that were in place were illegal by the own rules of the EU. The member states in question had called upon potential risks to the environment to ban these crops, but the EU's agency for risk had judged the crops to be safe.

The current legal regime for the approval of GM crops is roughly as follows. An applicant wishing to get authorization for putting a GMO on the market submits an application to a member state. In the first instant the member state (MS) checks the completeness of the application and forwards it to the European Food Safety Authority (EFSA). The scientific risk assessment studies are carried out by the applicants. The EFSA summarizes the application and forwards the summary to the member states and European Commission (EC). At the same time, they assess the evidence presented by the applicant and based on the assessment send an opinion to the EC. The opinion contains the assessment and proposals for labelling, and other possible risk mitigation measures deemed relevant should the GMO be placed on the market. Based on the opinion the EC drafts a decision, which is then submitted to be approved under the legal procedures of the EU.

The legislative process proceeds further as follows: the draft decision by the EC is submitted to an Examination Committee, that has to debate and agree or disagree on the decision by Qualified Majority Vote (QMV), i.e., a vote representing a majority of both member states and European population. If they agree or disagree by QMV the decision is respectively adopted or rejected. If no QMV is reached the Examination Committee delivers a no opinion on the draft decision. As GMOs are generally considered a safety issue, the EC cannot adopt the decision in that case but either has to amend the proposal and resubmit it to the examination committee, or submit the decision to the Appeal Committee. If the Appeal Committee agrees or disagrees by QMV, the EC must accordingly adopt or reject or change the decision. If the Appeal Committee also delivers no opinion the EC is flexible with regard to the decision and can choose to adopt it or change it and resubmit it to the examination committee.

The new framework as it stands is still relatively slow and allows for undue delays, for example through circles of drafting and redrafting or delaying the decision once the appeal committee delivers no opinion. Such procedures will result in increasing asynchronous approvals, and increase frustration with the trading partners. Whether or not that will lead to new challenges at the WTO is an open question.

4.10 GM crops in the pipeline

The focus of the literature and database study was confined to crops that are already authorized in the EU or elsewhere, or have progressed a long way in the research and development (R&D) stadium. Therefore the study comprises crops that are likely to be marketed in the near future (maximum 7-8 years).

There are six major crops for which there are a relatively large number of events available for cultivation worldwide: maize, soybean, cotton, oilseed rape, potato and rice. Table 2 gives an overview of the major crops. Furthermore a small number of events are available for: alfalfa, bean, flax, papaya, plum, sugar beet and wheat. In addition there are six crops which are either in the regulatory process somewhere or in the R&D pipeline, but not authorized anywhere yet: apple, barley, creeping bent grass, grapevine, poplar and sugarcane. In addition to the events described in the table there is the problem of stacked events, i.e. crops that have multiple traits, or the same trait from different genes. These are considered new crops in the EU even if the separate events have been authorized. This currently constitutes mainly a problem in maize, cotton and oilseed rape where a large number of stacks are available which are not authorized in the EU.

Table 2: Authorization, regulatory and R&D pipeline of major GM crops

Crop	Number of authorized events worldwide	Number of authorized events EU	Pending approval for import in the EU	Regulatory pipeline worldwide	R&D Pipeline
Maize	26	12	6	3	12
Soybean	15	6	7	4	6
Cotton	20	5	3	1	4
Oilseed rape	17	4	2	0	2
Potato	10	0	0	10	5
Rice	5	0	0	0	11

The authorized events are dominated by two agronomic traits: insect resistance and herbicide tolerance. However, there is a slow increase of other traits observable that start to appear in the commercial pipeline. These include agronomic traits like disease resistance or drought tolerance as well as quality ones, e.g. increased fatty acid or amylase expression.

Comparing the number of authorized events worldwide with the number of authorized for food and feed import in the EU and the number pending, we see large discrepancies. These differences show up especially for major crops like maize, soybean, cotton and oilseed rape and their stacks. Interesting in this respect is also the number of authorized events that are not submitted in the EU. Whereas 23% of the worldwide authorized events are also authorized in the EU and 14% are pending, 59% is not even submitted. This includes some crops that are unlikely to be exported to the EU or are not currently cultivated, but it includes some events in e.g. maize and soybean as well. Whether the developer has decided to leave the risk of low-level presence to the cultivators or exporters, or does not expect cultivation or export to the EU at all is unknown.

4.11 Future scenarios of international and EU supply chains

We brainstormed with selected stakeholders about the key driving forces influencing the segregation of GM and non-GM inputs along feed and food supply chains in the mid-tem future, i.e. until 2022. These were then clustered and the most uncertain and the one with highest impact were determined by majority vote. The two highest ranking were used to further develop scenarios. These were: 1) consumer perception of GMOs, and 2) the regulatory framework. Other high ranking factors were among others media and communication to consumers, innovative traits, EU governance, and the role of Europe in a long-term vision.

Consumer perception of GMOs and the regulatory framework were combined on two axes. Consumer perception of GMOs ran from negative to positive, regulatory framework from restrictive to enabling. Enabling was defined to make the approval of GMOs relatively easy, but not as a complete absence of regulation. These axes then formed the basis for four potential future scenarios: 1) an enabling framework combined with positive perception, 2) an enabling framework combined with negative perception, 3) a restrictive framework combined with positive perception and 4) a restrictive framework combined with negative perception. The first scenario was discarded as the stakeholders did not consider it to be too interesting. For the other three scenarios we developed storylines and how the supply chain would evolve under such a scenario.

The first analyzed scenario was that of an enabling regulatory framework combined with an increased negative consumers' perception of GMO's. The experts reasoned that this combination could arise through problems of asynchronous approval and WTO lawsuits especially regarding the soybean inputs that the EU requires for its food and feed industry. This will drive politicians to adopt a more enabling regulatory framework. The consumers, in contrast become increasingly aware of the scarcity of natural resources. Moreover they distrust science, the regulatory framework and large US biotech companies. The distrust could be further fueled by NGOs and the media who focus on the absence of consumer benefits of GM crops, as well as the absence of transparency in the supply chain, due to its complexity. We should, however, in this future distinguish between consumer and citizen. There is an important gap between what people say and what they buy. Price is important to the consumer but not so much to the citizen, and the question is whether the consumer will actually pay for the "GM-free" attribute. In general the experts did not see this future as very threatening, although they warn that the regulatory framework should not be completely abolished because this will further decrease citizen's trust. The opportunities in this future lay in an increase in investment in the life sciences, also within the EU, and the potential to further expand the “GM-free” market.

The second scenario analyzed a restrictive regulatory framework combined with a positive consumers' perception of GMOs. According to the experts the change in consumers' perception could occur in two phases: in the first phase the lack of GM food scandals combined with a slow move towards a more neutral vision of first generation GM crops, creates a positive attitude. When the second generation GM crops with real consumer benefits enter the market the perception of consumers becomes even more positive. Regarding the stricter regulatory framework two aspects were considered separately: lower thresholds for labeling food or feed as GM and more restrictions on allowed GM crops imports for the feed and food processing industry. Segregation would be introduced and enforced by the seed companies in this future.

In this future the higher demand for GM crops of the first generation is going to clash with the restrictive framework, which restricts supply. As consumers are no longer negative about GM crops "GM-free" will reduce to a small niche market or completely replaced by organic. The increasing prices of GM crops, due to the restricted supply, will spur further investment in development of 2nd generation crops with consumer benefits. This will make the consumers' perception of GM crops even more positive. These 2nd generation products can probably be sold at an even larger price premium and hence they are segregated from other GM crops. This will be enforced through even stricter labelling rules from private labels. The seed companies and other innovators will probably take the lead here. This will reverse the bargaining and market power within the supply chain from the players close to the consumer towards players at the very beginning. Some biotech companies will even integrate along the supply chain in order to make it more efficient. The strict private labels are not a problem because consumers are positive about GMOs.

If, in contrast the stricter regime translates in further restrictions on import, problems would arise. The reduction in imports would result in collapses in the EU feed and crushing industry, with knock-on effects to the European food industry. It would result in an increased import of final products such as chickens, rather than the ingredients. Opportunities in this future lay with the decreased costs of segregation in the first phase, as segregation is no longer necessary, as well as new opportunities for 2nd generation products and a shift in supply chain power for some companies. Threats are among others the increased concentration, with perhaps no room for new EU biotech companies, the losses in case of occurrences of adventitious presence under the stricter private standards, and the potential loss of the "GM-free" market.

The third scenario consisted of the combination of negative consumers' perception combined with a stricter regulation. Here too, experts emphasized that stronger regulation can take different forms such as full liability in all countries, lower labeling thresholds or required labeling of animal products from animals fed with GMOs. An even further negative consumer perception of GMOs could come about through food scandals or new scientific evidence. Within the scenario the experts emphasized that there were important differences between the effect of regulation on the feed and meat market on the one hand, and the market for GM food on the other. The experts thought the challenges of selling products derived from animals fed with non-GM tougher than selling non-GM food, which can be largely supplied through "GM-free" Europe. Therefore the focus of the scenario was put on the feed and meat market.

Stricter regulation would translate in making it increasingly difficult for the feed and meat producers to explain how the segregation and coexistence will be implemented. Moreover they would have to explain why there are thresholds, instead of a complete absence, as consumers would probably expect. The "capacity to prove" compliance to coexistence and segregation practices will be increasingly difficult, making the companies an easy target for media attacks, which could result in consumers asking for even stricter regulations. Thus the effective communication of the necessity of coexistence is a key factor for the industry. The stricter regulation will also result in an even slower approval of GM events and increasing risks of adventitious and low-level presence. This in turn will lead to trade disruptions and possible repercussions on the WTO level. The stricter regulations will result in increasing costs of certified “GM-free” feed stuffs. As a consequence consumer prices will rise, if consumers are actually willing to pay a premium for non-GM. They may not be willing to pay an extra price above a certain level.

Threats in this scenario come from the increasing costs of coexistence, price rises of meat and other animal products and potential trade disruptions. Opportunities lay in the further development of the “GM-free” markets, especially if Europe can actively sell this attribute and export “GM-free” products to other countries. This would require, however, a large increase in either certified “GM-free” feed resources, either from within Europe or from outside of Europe.

4.12 Overall results and conclusions

The analyses of the separate supply chains for soybeans and maize in Europe and Brazil show that these are often highly concentrated although there are large local differences. The large multinationals play a role in all countries, sometimes they have the full supply chain integrated and a separate smaller supply chain is present, sometimes they are simply important players at the top. There are basically two strategies to manage the segregation of "GM-free" and GM crops: working with dedicated facilities, or flushing and cleaning. The former is easier to implement, but requires relatively large firms, and moreover dedicated plants are often not able to work at full capacity. Asynchronous approved events are managed by importing mainly from countries where there is only a small amount of asynchronictity such as Brazil or Argentina, or no issue at all because the country in question does not cultivate GM crops. Portugal is an exception in this regard as it also imports relatively large amounts from the United States. Switzerland is completely "GM-free", but pays a high price for this, and given the growing amount of GM crops worldwide it is questionable how long it can keep this position.

The "GM-free" dairy in Germany is mainly a niche market. The dairies themselves which are "GM-free" tend to be culturally close to conventional dairies. They are in general somewhat more positive about the market and risks of "GM-free" production, albeit not as positive as the organic dairies. The dairies also expect "GM-free" to remain a niche market. The "GM-free" maize bread in Portugal is also a niche market, with many small players. Segregation is not practiced in too much detail, as is shown by the analysis of the bread samples: all contain traces of GM events, some over the labeling threshold. It is unclear where exactly the mixing of GM and non-GM takes place but it is not at the farm level.

Although the current EU regulation is more or less in line with WTO regulation there are still a number of weak spots, where undue delays are possible. Moreover, until now the WTO has not ruled on a number of important issues that may be the source of further debate. Up to now Europe seems to be able to manage its problems with asynchronous and asymmetric approval, but given the large number of events in the pipeline the risks of trade disruptions and further WTO cases becomes all the more likely.

The scenario analysis has shown that according to supply chain members the most important factors for the future are the consumer perception of GMOs as well as the development of the regulatory framework. Currently they are such that the supply chain is able to manage the segregation. However, further restrictions could be catastrophic. Rising prices of fresh products in Europe, a collapse of the feed industry and increasing imports of frozen and processed food are possible outcomes.

Potential impacts and dissemination activities

1 The PRICE project and its consortium

The PRICE project was a small collaborative project addressing the coexistence of GM and non-GM crops both at the farm level and further down the supply chain. Within the FP 7 program the project fell under Thematic Area Food, Agriculture, Fisheries, and Biotechnology, Activity 2.1: Sustainable production and management of biological resources from land, forest and aquatic environments, Area 2.1.4 Socio-economic research and support to policies, topic: KBBE.2011.1.4.-03: Feasible and cost-effective crop-specific coexistence measures.

The consortium covered a wide range of partners: universities, research institutes and several small-medium enterprises (SMEs) from all over Europe. In addition, the project was interdisciplinary covering researchers with diverse backgrounds such as agricultural economists, agronomists, molecular biologists, computer programmers and communication experts.

2 Topic related impacts

Under the topic KBBE.2011.1.4.-03: Feasible and cost-effective crop-specific coexistence measures the PRICE project contributed to the following impact areas:

1. A greater integration of research actors and activities from across the enlarged European Union and the candidate countries.

The project covered partners from several recent new member states in Eastern Europe and Southern Europe. These were part of the project from the beginning and actively took part in all activities. In addition there were exchanges such as key notes at locally organized conferences, and proposals for follow-up research involving these partners.

During the stakeholder meetings policy makers from candidate countries (e.g. Croatia) and recent members (e.g. Lithuania) joined and discussed the research plans and outcomes of the project, putting both the research itself and its results in a wider European context.

2. Supporting coherent and practical implementation of feasible and cost-effective crop specific coexistence measures and labelling and traceability requirements.

We supported the development and implementation of these measures by investigating their potential costs at farm level in WP 2, their effectiveness and implementation in WP 3 and WP 4 and the effects further down the supply chain in WP 5. The results of WP 2 show which coexistence measures farmers use and prefer to use, as well as the effect of their implementation on adoption of GM crops. This information is a basic ingredient required for any well-designed coexistence policy. Equally important, is the efficacy of the potential coexistence measures at farm level. Within WP 3 we have shown which measures are very efficacious, and which ones are less so. The results of WP 4 including the decision-support tool and the Bayesian models make the planning of these measures in the landscape easier, and show the effect of e.g. applying a uniform isolation distance as a policy.

Moreover, the tool has been built in such a way that it can easily interface with Public Registers. A public register has also been designed, which is flexible enough to be carried over to other countries and used there. WP 5, show the current state of the supply chain and how they deal with labelling and traceability requirements. The scenarios developed within this WP provide important information about the driving factors within these supply chains as well as the expected effects of regulation and labeling. More details can be found in the table below.

Coexistence issue	Impact of PRICE
GM farmers' best practices	PRICE has conducted case studies among farmers in EU Member States planting GM crops using a standardised approach to, firstly, identify coexistence compliance costs under different settings and secondly, identify successful strategies farmers use to reduce coexistence compliance costs by cost-effectiveness analysis (CEA). This kind of comparative analysis is a new contribution to the debate about benefits and costs of coexistence policies in the EU.
Ex-ante regulation and ex-post liability under irreversibility and uncertainty	PRICE has applied the theoretical MISTIC model to assess new coexistence measures and their combinations for GM crops. This is a novel contribution to the agricultural economic literature on the regulation of externalities.
Contribution of asynchronous flowering for achieving coexistence	PRICE has tested the efficacy of asynchronous flowering under field conditions in Spain and validated results of the SIGMEA project.
Contribution of cytoplasmic male sterility for achieving coexistence	PRICE has assessed the performance of CMS maize in various landscapes of Germany, Spain, and the Czech Republic. The research results show how GM-CMS-maize could reduce already implemented isolations distances and other coexistence measures in relation to different thresholds.
Decision-support tool (DST) combining technical, organizational and cooperative measures under uncertainty for achieving coexistence at farm and regional level	PRICE has developed a user friendly decision-support tool combing technical, organisational and cooperative measures under uncertainty for achieving coexistence at farm and regional level.
Harmonizing the EU wide public register of GM fields	PRICE has adapt the national German register to an EU wide user friendly platform by: 1) transformation into an open source software package; 2) development of interfaces to use of geo-referenced GIS datasets, and; 3) considering of specific requirements of EU Member States
Challenges for international and EU supply chain	PRICE has evaluated implications of coexistence and segregation along the entire supply chain under an industrial organization and institutional perspective.

3. Results clearly of interest to SMEs

SMEs have formed an integral part of the PRICE project. Three partners within the consortium were SMEs themselves: Schenkelaars Biotechnology Consultancy (SBC), Geosys and Lisconsult (LIS). Both SBC and LIS were responsible for a part of the management and more importantly the communication about the project. Geosys is a SME specializing in geo-referenced software and was the main partner responsible for the development of the web-based decision-support tool (DST). The PRICE project has provided these SMEs with valuable employment and experience, and in the case of Geosys, a prototype that may, after further development, be exploited as a commercial product. The DST itself was developed such that it is of interest to SMEs. To this end we worked closely with potential end-users e.g. through the subcontractor ARVALIS.

A number of subcontracts were also awarded to SMEs. The design of the PRICE logo was awarded to Identim, a one-man company specializing in graphic design. Similarly the film portraits were awarded to Agrapen, a one-man company specializing in text and film productions.

Finally the results of the farm survey as well as the information on efficacy of other coexistence measures are of interest to farmers because they now know, also from a scientific perspective which coexistence measures work and which ones do not.

3 Contribution to Area 2.1.4 Socio-economic research and support to policies.

The PRICE project contributed to two important impact areas within Area 2.1.4

1. Providing the tools needed by policy makers and other actors to support the implementation of relevant strategies, policies and legislation and in particular to support the building of the European Knowledge Based Bio-Economy and the needs of rural and coastal development.

PRICE has brought public research institutes and SMEs that cover the EU farming topography together in a consortium with a Scientific Advisory Board and a Stakeholder Platform that consists of stakeholders, including policymakers, regulators, biotech firms, seed companies, farmers, agro-food/feed chain operators, retailers and consumer and environmental organisations. The main objective was to address new and emerging research issues in relation to the social, environmental and economic challenges posed by the practical implementation of coexistence of the cultivation of GM and nonGM crops in Europe and international supply chains of GM and nonGM food/feed ingredients. Moreover by involving the stakeholders through e.g. workshops, the website and newsletters we supported the coherent and practical implementation of feasible and cost-effective crop-specific coexistence measures and labelling and traceability requirements including a wide range of researcher and research activities from across the enlarged European Union and candidate countries.

Given the challenge of securing the availability of safe, nutritious and affordable food that has taken on a new dimension in view of increase in global demand, environmental restrictions on agricultural production and intensified competition for land for feed, food and non-food production, farmers and consumers in the EU have so far had limited choice to benefit from the agricultural, nutritional and environmental advantages potentially offered by the cultivation of GM crops in the EU. Building on knowledge and experience gained with a series of EC funded research projects on GMO impacts and coexistence, PRICE has developed practical coexistence measures, and in particular through the development of a

1. user-friendly Decision Support Tool at the farm and regional level, and

2. a Europe-wide harmonised system for public registers of GM crop cultivation in line with EU regulatory requirements for GM crop cultivation.

The delivery of practical coexistence measures by PRICE will thus enable farmers and agro-food/feed chain operators to make better use of the opportunities that GM crops and GM food/feeds offer and coexistence policymakers and regulators to fulfil their legal duties and tasks more effectively and efficiently, provided that the cultivation of GM crops is allowed in other European countries.

It is expected that our research on cost-effective practices and efficient choices will promote a feasible coexistence and therefore the freedom of choice of producers in deciding whether to supply a GM or no-GM supply chain or both. At the same time, they will reduce the social cost of the necessary segregation that guarantee the freedom of choice to consumers on whether to consume or not GM products.

2. Research for all policies, including the Common Agricultural Policy , will include socio-economic studies and cost-benefit analysis, comparative investigations of different faming systems including multifunctional once, …, and studies to improve rural and coastal livelihoods.

The challenge of securing the availability of safe, nutritious and affordable food has taken on a new dimension in view of increase in global demand, environmental restrictions on agricultural production and intensified competition for land for feed, food and non-food production. With a view to increase agricultural productivity sustainably in Europe, relatively new options for farmers, like the cultivation of GM crops, have so far been impeded by a large lack of practical implementation measures for coexistence in many European countries. Likewise, options for agro-food chain operators to supply markets with GM and nonGM products have been impeded, largely because of the asynchronous approval procedures for GM crops and GM food/feed ingredients between the EU and its major trading partners. Building on knowledge and experience gained with a series of EC funded research projects on GMO impacts and coexistence, PRICE has researched practical coexistence measures. Moreover through the development of a user-friendly decision-support tool at the farm and regional level and a Europe-wide harmonised system for public registers of GM crop cultivation in line with requirements of Directive 2001/18/EC on the deliberate release into the environment of GMOs, PRICE has contributed to the potential development of feasible coexistence policies. The delivery of practical coexistence measures by PRICE will eventually enable farmers and agro-food/feed chain operators to make better use of the opportunities that GM crops and GM food/feeds offer and coexistence policymakers and regulators to fulfil their legal duties and tasks more effectively and efficiently.

The practical coexistence measures that PRICE will deliver will help sustainable production and management of biological resources from land by enabling farmers to exercise choice between GM crops and nonGM crops with a view to sustainable production and management of biological resources on their land. A major share of the scientific-technical research consists of socio-economic research as an indispensable requisite for the development of a user-friendly DST for coexistence at the farm and regional level and a Europe-wide harmonised system of registers of GM crop cultivation in line with requirements of Directive 2001/18/EC on the deliberate release into the environment of GMOs.

4 Contribution to the Thematic Area Food, Agriculture, Fisheries, and Biotechnology

The major impact of the thematic area can be summarized as follows:

Support the development of a sustainable European Knowledge Based Bio-Economy.

The outputs from the PRICE project can be used in key strategic areas including sustainable and secure agricultural production, its socio-economic factors, regulation and decision making and the involvement of major players in the overall management processes. The project is therefore entirely consistent with the overall objectives and deliverables of the EC's 7th Framework Programme on Knowledge Based Bio-Economy (KBBE): PRICE has delivered knowledge to support exploitation of new and emerging technologies in crop production regarding the environmental and economic challenges, the growing demand for safer, healthier and higher quality food and the sustainable use of renewable bio-resources.

Given the heterogeneity of characteristics and functioning of farm systems and supply chains across Europe, feasible coexistence has a clear European dimension in this project.

In particular, the European dimension is important to: (i) identify the differences in successful strategies and cost-effective measures of coexistence at the farm level across EU Member States and regions; (ii) test the validity of the developed Decision support tool (DST) across the EU heterogeneous territory; (iii) harmonize the EU wide public register of GM fields; (iii) evaluate the different structure and functioning of the food and feed supply chains across the EU and the different impact of the risk of adventitious presence of GM products in GMO-free chains; (iv) identify which elements of future scenarios are common for EU Member States and which elements impact territories with specific characteristics.

The overall "EU value" of the project will be ensured by the collaboration of experts and scientists of the Consortium from eleven countries coordinated by a clearly defined management structure and by the interaction of members from the Consortium with the Scientific Advisory Board and the Stakeholder Forum. Project results have gone over the boundaries of the Member States involved in the project and will impact the overall EU community.

Finally, higher education across the EU will benefit from the development of project since a large part of the permanent staff members in the project are engaged in lecturing in universities across the EU. This will facilitate the transfer of a science-based knowledge about coexistence in teaching activities and research supervision.

5 Dissemination of results

5.1 General dissemination of results

The basics for the dissemination of the results of the project were laid down in the communication plan as well as the consortium agreement at the beginning of the project. Although controversial for some stakeholders, there is a wide range of stakeholders interested in coexistence. An overview of the different stakeholders and their interests in coexistence is provided in the table below.

Stakeholder type	**Type of stake in coexistence**
EC and national authorities for 2001/18/EC and 1829/2003	Regulating GM crop imports and cultivation, GM foods/feeds, formulating and implementing coexistence rules
EC and national policy makers and scientific advisors on coexistence	Formulating and implementing coexistence rules
Scientists working on coexistence	Coexistence as a research subject
Agricultural input companies	Achieving coexistence, facilitating GM and non-GM crop cultivation, avoiding trade disruptions
Seed firms	Achieving coexistence, facilitating GM and non-GM crop cultivation, avoiding trade disruptions
Farmers	Achieving coexistence, facilitating GM and non-GM crop cultivation
Farmers (organic)	Avoiding GM crops and GM contamination, dealing with liability
Traders	Achieving coexistence, avoiding trade disruptions
Feed manufacturers	Achieving coexistence, avoiding trade disruptions
Primary food processors	Achieving coexistence, avoiding trade disruptions
Food manufacturers	Achieving coexistence, avoiding trade and sales disruptions
Retail firms	Achieving coexistence, avoiding sales disruptions
Consumer NGOs	Achieving coexistence, exercising consumer choice
Environmental NGOs	Criticizing GM crops and thus coexistence and coexistence measures
Politicians	From achieving to criticizing coexistence; not an ‘attractive’ issue for gaining a high political profile
Journalists	Reporting newsworthy coexistence stories
Lay-audiences	Various attitudes to GM foods, but mostly unaware of the specific issue of coexistence

Such different audiences, with different interests, required different communication strategies and different approaches and as such the PRICE project has used several outlets for communication.

As a first step stakeholders were divided into an "inner circle" of stakeholders with more direct stakes in coexistence, and an "outer circle" with less direct stakes. The inner circle comprised EC and national authorities and policy makers, firms involved in the supply chain, scientists working on coexistence, as well as organic farmers, consumer and environmental NGOs. The outer circle in contrast consisted of the politicians, journalists and lay-audiences. Communication with the inner circle was different from that with the outer circle. Whereas the inner circle received extra attention when communicating the results, the outer circle was only addressed through communication efforts aimed at all stakeholders.

The communication efforts aimed at all stakeholders involved the following actions:

A public website, including Web 2.0 applications. The website contains information about PRICE in various forms, such as the work description, public reports of events organized by PRICE, a blog with comments on the work in progress and relevant incidents reported by traditional and social media, links to other relevant EU projects, past and present publications, press briefings, newsletters and the six film portraits (see below). The website is maintained for a year after the project has ended in order to ensure a continuous presence on the world wide web

Six film portraits of stakeholders. Six film portraits have been made of different stakeholders: 1) a European farmer; 2) The Portuguese organic sector; 3) A scientist responsible for PRICE field trials; 4) A retailer marketing and selling products from animals fed with non-GM feed; 5) The non-GM maize food chain in Portugal; 6) The scientist developing a Decision Support Tool. The film portraits have been used as tool for facilitating discussions at the stakeholder dialogue workshops and European conference (see below), and have also been used in university lectures and other courses. The film portraits have been posted on the PRICE website as an interactive tool for communication with stakeholders. In addition, the film portraits are available from YouTube.

Four e-newsletters. Four e-newsletters have been produced with information about the PRICE work-in-progress and preliminary findings and interviews with PRICE partners and stakeholders.

A LinkedIn group on Coexistence. A coexistence LinkedIn Group linked to the website meant to highlight and discuss PRICE events and PRICE related issues in the media was created and maintained. Over 300 stakeholders have been invited to join the Group. So far, the group has 47 members and 38 issues have been posted.

The inner circle of stakeholders was in addition approached through:

Representation in the scientific advisory board of the project. Invitations were sent to Copa-Cogeca, Europabio and EFSA. Of these three only Europabio accepted. The rest of the scientific advisory board consisted of scientists and independent consultants working on coexistence.

Three workshops and a European conference.

- The first workshop took place in Brussels on 14 November 2012. In total there were 35 stakeholders representing farmers, the biotechnology industry, scientists, policy makers and environmental NGOs. Participants came from different European countries including new member states, candidate member states and Norway. The focus of the workshop was on the general set-up of the project and the first preliminary and expected results.
- The second workshop took place in Lisbon, on 13 November 2013, back-to-back with the GMCC 2013, the largest scientific conference on coexistence between GM and non-GM crops. The focus of this workshop was on coexistence implications within the EU and international supply chain. The workshop was attended by 30 participants, coming from European countries as well as Japan, Korea and the United States. Most of them represented research institutions and (seed) companies, while a single person represented an environmental organization.

- The third workshop focused on scenarios for coexistence in the supply chain and was organized in co-operation with WP5. It took place in Brussels on 10 - 11 September 2014. This workshop was attended by 23 external participants, representing the whole European supply chain from seed to retailer. As this workshop was focused on scenario development participation was by invitation only, and the total number of participants was kept relatively small.
- The final conference took place in Freising, Germany, on 19 February 2015. The project's final results were presented through a general introduction by the project leader and talks by the leaders of WP 2-5 and three interactive sessions, using the prototype of the Decision Support Tool developed in WP4, the scenarios developed in WP5, and the film portraits developed in WP6. The Conference was attended by 50 participants (30 PRICE partners).

Finally, to further address the scientific audience, a number of papers were published in scientific journals or are currently in preparation. Examples of the journals include Agbioforum, Crop Science, Ecological Economics, Ecological Informatics, European Review of Agricultural Economics and the Journal of Agricultural Science and Technology. Moreover we are preparing special issues in Eurochoices and NJAS - Wageningen Journal of Life Sciences about the PRICE project as a whole, as well as a special section on WP 2 in Agbioforum. The results of the project have frequently been presented at international conferences, such as International Consortium on Applied Bioeconomy Research (ICABR), the GMCC, the International Conference of Agricultural Economists, the European Conference of Agricultural Economists, the World Conference of Environmental Economists and the American Conference of Agricultural Economists. We hosted special PRICE sessions at ICABR 2013 and the GMCC 2013 and will organize special session on the PRICE results during the GMCC 2015 as well.

More information

Public website: http://price-coexistence.com/
Linkedin group: https://www.linkedin.com/grp/home?gid=5162580
Youtube film portraits: https://www.youtube.com/user/PriceCoexistence

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