EUROPEAN COMMISSION
DIRECTORATE-GENERAL JRC
JOINT RESEARCH CENTRE
Institute for Prospective Technological Studies (Seville)
Sustainability in Agriculture, Food and Health

GM crops in EU agriculture

Case study for the BIO4EU project

Draft final – version 15 January 2007

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Index

List of tables

List of figures

1. Scope and structure of this case study

The present case study for the BIO4EU project aims at estimating the impacts of the uptake of Genetically Modified crops (GM crops) in the agriculture sector of the European Union.

In line with the scope of the BIO4EU exercise, this case study focuses on commercialised technology, i.e. on GM crops authorised for cultivation, to understand impacts of existing GM crops rather than projected impacts from current research and development pipelines.

However, since many GM crops are commercially available elsewhere, this case study also considers anticipated impacts from current GM crops widely cultivated elsewhere if they were to be introduced into EU agriculture.

The case study proceeds as follows. Section 2 presents those GM crops that are commercially available and the uptake of these world-wide. It then reviews the particularities of the uptake in the EU and concludes with a summary of attempts made so far to estimate the socio-economic impacts of GM crops adoption world-wide.

Section 3 focuses on the evidence *ex post* (after adoption of the technology) of the socio-economic impacts of GM crop cultivation by EU farmers. Currently, such evidence is only be available for one crop (Bt maize) and one EU Member State (Spain) where adoption started in 1998. Section 3 reports the main results of original research performed by JRC-IPTS on the socio-economic impacts of Bt maize in Spain. The section is completed with a review on the environmental impacts of Bt maize introduction in Spanish agriculture. These impacts are compared with effects of adoption of Bt maize elsewhere.

Section 4 reviews research addressing *ex ante* the potential adoption and economic impacts of GM crops not yet approved for commercial cultivation by EU farmers, but cultivated elsewhere. Consumer and regulatory issues that will affect the economic impacts of GM crop introduction, such as market segmentation, costs of identity preservation and measures to ensure coexistence with non-GM crops, are also reviewed.

2. GM crops: technology available and adoption rates

2.1. Main GM crops available

Genetic modification, also known as genetic engineering or recombinant DNA techniques, is one of the newest methods to introduce novel traits[1] to plants.

During the first decade of commercial GM crop cultivation (1996-2005), two agronomic traits introduced by genetic engineering into a few major crops have dominated the market. The introduced traits are herbicide tolerance[2] (referred to as **HT crops** in this paper) and insect resistance (referred to as **Bt crops** since the gene conferring resistance comes from the soil bacterium ***B****acillus* ***t****huringiensis*).

Table 1 summarises the evolution of the world agricultural area cultivated with the dominant GM crop-trait combinations.

1 One of the many characteristics that define an organism.

2 Herbicide Tolerance refers here to so-called total herbicides (glyphosate and gluphosinate) obtained by transgenesis (Genetic Modification). Crop varieties tolerant to herbicides have also been generated by mutagenesis and/or selection.

By 2005, the HT trait had been introduced into four major crops and commercial HT varieties were grown for soybean, maize, cotton and canola (a type of oilseed rape). About 71% of the global GM crop area in 2005 was planted with HT crops.

Insect resistant (Bt) crops were second after HT crops, with an estimated global share of 18 % of GM crop area. By 2005, insect resistance Bt genes[3] were commercially used in varieties of maize and cotton.

Finally, the combination ("stacking") of the two traits, HT and Bt, in the same crop is growing rapidly and available "stacked" **HT/Bt crops** (cotton and maize) now account for 11% of the total GM crop area.

Table 1: Dominant GM crops during 1996-2005

Crop/trait combination	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2005**
	(million hectares)										**% total GM crop area**
HT soybean	0.5	5.1	15	21.6	25.8	33.3	36.5	41.4	48.4	54.4	60.44
Bt Maize	0.3	3	7	7.5	6.8	5.9	7.7	9.1	11.2	11.3	12.56
HT Maize	0	0.2	2	1.5	2.1	2.4	2.5	3.2	4.3	3.4	3.78
Bt/HT Maize	--	--	--	2.1	1.4	2.5	2.2	3.2	3.8	6.5	7.22
Bt Cotton	0.8	1.1	1	1.3	1.5	2.1	2.4	3.1	4.5	4.9	5.44
Bt/HT Cotton	0	<0.1	--	0.8	1.7	1.9	2.2	2.6	3	3.6	4.00
HT Cotton	<0.1	0.4	--	1.6	2.1	1.8	2.2	1.5	1.5	1.3	1.44
HT Canola (oilseed rape)	0.1	1.2	2	3.5	2.8	2.7	3	3.6	4.3	4.6	5.11
Total	**1.7**	**11**	**27**	**39.9**	**44.2**	**52.6**	**58.7**	**67.7**	**81**	**90**	**100**

Source: Adapted from ISAAA(2004) for 1996-2003, from James (2004) for 2004 and, from James (2005) for 2005

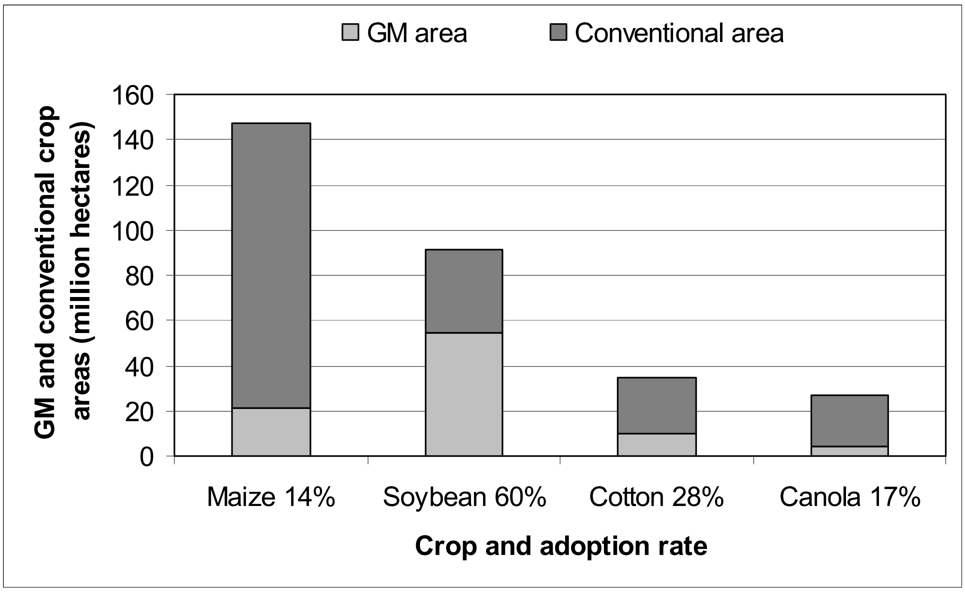
2.2. Global adoption rates for available GM crops

During this decade (1996-2005), GM crops have been adopted by farmers in many areas of the world. Today, GM varieties[4] have a significant share of the four major agricultural crops for which they are commercially available (maize, canola, soybean and cotton). Figure 1 shows the share of GM varieties for these major crops globally. By 2005, 60% of world's soybean area corresponded to GM varieties. GM varieties now account for 28% of cotton, 17% of canola and 14% of maize cultivated area.

3 Bt genes for insect resistance are a large family; several are used commercially for different pests; more than one Bt trait for different pests can be introduced into the same crop.

4 Variety: a defined strain of a crop plant, selected on the basis of phenotypic (sometimes genotypic) homogeneity (FAO glossary for biotechnology).

Figure 1: Global adoption rates for major GM crops in 2005



Source: Adapted from (FAOSTAT, 2006, James, 2005)

Adoption of GM crops has been progressing at a faster pace than has been the case for other innovations in plant varieties, such as the introduction of hybrid maize decades ago (Kalaitzandonakes, 1999). In the first year of introduction (1996) about 1.7 to 2.6 million hectares of GM crops were grown, almost exclusively in a single country (the USA). Ten years later (2005) the area under GM crops had expanded to 90 million hectares in 21 countries of which 7 are high-income economies, and 14 are developing countries (James, 2005)[5]. Table 2 illustrates the evolution of the global GM crop area and grower countries. The global area under GM crops has increased every year, at an average rate of 15% since 2000.

The distribution of the area between countries has been always very asymmetrical. In 2005, eight countries accounted for 99% of the global GM crop area. This year the US alone accounted for 55% of total area, followed by Argentina (19%), Brazil (10%), Canada (6%), China (4%), Paraguay (2%), India (1%) and South Africa (0.6%). The remaining 2% was shared by the other 9 countries.

5 The International Service for the Acquisition of Agri-biotech Applications (ISAAA) produces each year a global review of commercial genetically modified crops. It is considered as the most comprehensive source for figures of areas under GM crops and it widely use in scientific literature. However, in order to diversify sources, ISAAA figures have been confronted and, where relevant, complemented with other figures.

Table 2: Global area under GM crops and grower countries

Year	Area (Mio hectares)	Countries
1996	2.8	US, China, Canada, Argentina, Australia and Mexico
1997	12.0	US, China, Canada, Argentina, Australia and Mexico
1998	27.8	US, China, Argentina, Canada, Australia, Mexico, Spain, France and South Africa
1999	39.9	US, Argentina, Canada, China, Australia, South Africa, Spain, France, Portugal, Romania and Ukraine
2000	44.2	US, Argentina, Canada, China, South Africa, Australia, Romania, Mexico, Bulgaria, Spain, Germany, France, Portugal, Ukraine and Uruguay
2001	52.6	US, Argentina, Canada, China, South Africa, Australia, Mexico, Bulgaria, Uruguay, Romania, Spain, Indonesia and Germany
2002	58.7	US, Argentina, Canada, China, South Africa, Australia, India, Colombia, Honduras, Mexico, Bulgaria, Uruguay, Romania, Spain, Indonesia and Germany
2003	67.7	US, Argentina, Canada, Brazil, China, South Africa, Australia, India, Colombia, Honduras, Mexico, Bulgaria, Uruguay, Romania, Spain, Indonesia, Germany and Philippines
2004	81	US, Argentina, Canada, Brazil, China, South Africa, Australia, India, Colombia, Honduras, Mexico, Paraguay, Uruguay, Romania, Spain, Germany and Philippines
2005	90	US, Argentina, Canada, Brazil, China, South Africa, Australia, India, Colombia, Honduras, Mexico, Paraguay, Uruguay, Romania, Spain, Germany, Philippines, Iran, Portugal, France and Czech Republic

Source: For years 1996 and 1997 data are from (James, 1997), for 1998 (James, 1998), for 1999 (James, 1999), for 2000 (James, 2000), for 2001 (James, 2001), for 2002 (James, 2002), for 2003 (James, 2003), for 2004 (James, 2004) and for 2005 (James, 2005)

2.3. Availability and rates of adoption of GM crops by European Union farmers

Despite the wide adoption of GM crops at global level, there has been little adoption of these crops in Europe.

First, the number of GM crops authorized for cultivation in the EU is small when compared with other world regions. This is not the case of GM crops authorized for import and processing into the EU, but not for cultivation. In this category the numbers of authorized crops are larger (Table 3).

Table 3: List of event transformations currently authorized in the UE, US and South Africa[6]

Country/Union	GM crop	Number of authorized event transformations	Intended effect
EU (for cultivation)	Maize	2	Insect resistance
	Total	**2**	
EU (for import and processing only)	Canola (oilseed rape)	4	Tolerance to gluphosinate ammonium
	Cotton	3	Herbicide tolerance
	Maize	3	Either herbicide tolerance, insect resistance or both
	Soybean	1	Herbicide tolerance
	Total	**11**	
US	Canola (oilseed rape)	11	Either herbicide tolerance, high laureate or degradation of phytase in animal feeding
	Cotton	11	Either insect resistance, herbicide tolerance or both
	Maize	17	Either insect resistance, herbicide tolerance, both or increase lysine level for use in animal feed
	Soybean	3	Either herbicide tolerance or high oleic acid soybean oil
	Total	**42**	
South Africa (for cultivation)	Cotton	3	Either insect resistance, herbicide tolerance or staked
	Maize	3	Either insect resistance or herbicide tolerance
	Soybean	1	Herbicide tolerance
	Total	**7**	

Source: Adapted from (Agriculture, 2006, Commission, 2006, US.FDA, 2006)

In practice, the only GM crop currently available to EU farmers for cultivation is a GM maize resistant to insects, commonly known as Bt maize. Since its first introduction in 1996 in the USA, Bt maize has become the second GM crop world-wide in terms of area sown (11.3 million of hectares or 12.56 % of the global GM crop area in 2005) (James, 2005)[7].

Within the EU, Spain is the only country growing Bt maize at a significant rate. Spain cultivated about 53 225 hectares of Bt maize varieties in 2005 (MAPA, 2005), which accounts for 13 % of the national maize area. France, Germany, Portugal and the Czech Republic also grew Bt maize in 2005 but reporting areas in the order of one-thousand hectares or less.

Table 4 summarizes figures on GM maize adoption rates in the EU and world-wide to serve as comparison. In the EU25 the share of GM maize area out of the total maize area does not reach 1% while in the US this figure accounts for 52%.

6 The US and South Africa are countries for which literature on socio-economic impacts have been found. These countries serve as comparison with the EU case.

7 Examples of countries with commercial growing of Bt maize are the USA, Canada, Spain, Argentina, Honduras, South Africa, Uruguay, and the Philippines.

Table 4: GM maize adoption rates in different countries, the EU and the World in 2005

Phenomenon	Indicator	Value		Source
Adoption rate	Share of GM maize area out of total grain maize area			
	53 225 ha/421 724 ha	in Spain	12.62%	(MAPA, 2007)
	500 ha /1 654 000 ha	in France	0.03%	(EUROSTAT, 2006, James, 2005)
	300-500 ha/443 000 ha	in Germany	0.07%	
	150 ha/ 98 000 ha	in Czech Republic	0.15%	
	750 ha/110 000 ha	in Portugal	0.68%	
	54 925 ha/6 590 000 ha	in the UE25	0.83%	
	15 649 920 ha/30 096 000 ha	in the USA	52%	(USDA, 2005, USDA, 2006)
	289 000 ha/1 700 000	in South Africa	17%	(James, 2005)
	21 200 000 ha/147 000 000	in the World	14%	(FAOSTAT, 2006, James, 2005)
Note: In the USA GM maize can be either Bt maize, Herbicide Tolerant (HT) maize or HT/Bt maize while in the EU is only Bt maize.				

As expected, and due to the little adoption of GM crops in EU agriculture, researchers have given little attention to *ex post* impacts in the EU. Currently, *ex post* impacts can only be estimated for significant temporal series and rates of adoption in the case of Bt maize in Spain. This is done in Section 3 of this case study, together with a detailed description of the process of commercial release and adoption by Spanish farmers of Bt maize varieties.

2.4. Estimating the socio-economic impacts of GM crops world-wide

Analyses ex post of the effects derived from the adoption and diffusion of GM crops are of two types. The first and most frequently performed analysis deals with the "local", farm-level impacts of adoption and the second with the aggregated effects and economic welfare distribution. Farm-level analyses are usually based on surveying samples of farmers (adopters and non-adopters of the technology). They provide data on the economic and agronomic performance of the GM crop and on the use of inputs (pesticides, energy) compared with conventional crops. Results produced by farm-level studies constitute the bases for aggregate studies. These studies estimate the economic welfare generated by adoption of GM crops, and its distribution among the economic agents (farmers, seed suppliers and research companies, consumers) or geographical regions. The significance of aggregate results depends obviously on the quality of farm-level data.

During this first decade of introduction of GM crops in agriculture, socio-economic research on the *ex post* impacts GM crops world-wide has accumulated, and reviews on results obtained for developed and developing countries have been published recently. The JRC-IPTS has published a review that covers both developed and developing countries and both *ex post* and *ex ante* approaches (Gómez-Barbero and Rodriguez-Cerezo, 2006). Also, scientists from the UN Food and Agricultural Office (FAO) have released two reviews with emphasis on developing countries (FAO, 2004, Raney, 2006).

The reviews show that *ex post* analyses are now numerous and cover (with different degree of detail) the four GM crops dominant world-wide in the following countries: Argentina, India, China, South Africa, Mexico and the US. It is not in the scope of this case study to describe in detail the results from *ex post* analyses of GM crops world-wide, but some general conclusions emerging from the reviews can be outlined. GM crop adoption results in net economic gains at farm level, although variable in space and time. The studies published do not support the claim that current GM crops benefit only large holdings. On the contrary, the size of the farm does not seem to be an obstacle for adopting the technology and in some crops (particularly cotton) increases in gross margin are comparatively larger for smaller and poorer farms. From aggregate analyses (of which there is fewer number than on-farm analyses) the picture emerging is that the welfare created by GM crop uptake in agriculture is shared mainly by adopting farmers and by seed developers, and in some cases by consumers due to lower market prices. The share of the benefits between adopting farmers and seed developers is variable and depends on a key parameter (GM seed price premium compared with conventional seed) which at the end is influenced by the intellectual property regime affecting GM seeds in each particular country.

3. Adoption of Bt maize by farmers in Spain and socio-economic impacts: an *ex post* analysis

All results described in this section (except 3.8 on environmental impacts) derive from original research performed by JRC-IPTS, which is yet unpublished. The research has been performed under the project SIGMEA[8] funded by the EC's VI Framework Program. A full report including raw data on the results obtained so far on Bt maize in Spain is provided separately to this case study for further reading.

3.1. A brief description of the Bt maize technology

Insect pests of agricultural crops are a major problem worldwide and maize is no exception to this. The Mediterranean Corn Borer (MCB), *Sesamia nonagrioides*, appears to be the most damaging pest of maize in Spain and other Mediterranean countries, provoking significant yield and economic losses. Damage from these pests is caused by insect feeding and from stalk tunnelling damage causing plant lodging and further losses at harvest.

Chemical control of maize borers in conventional maize crops is particularly difficult because insecticide sprays are effective only in the narrow time span between egg hatch and larvae boring into stems. The lack of effectiveness and cost of control measures are the reasons why many maize farmers do not spray insecticides specifically for controlling corn borers but tend to assume the yield losses.

Bt maize is the common name given to genetically modified varieties of maize expressing the insecticidal toxins from the soil bacterium Bacillus thuringiensis (Bt). The plants become then genetically resistant to corn borer attacks. Therefore higher yields are expected in areas where corn borers are a problem. However, like for most pests, the intensity of the corn borer attack and the yield losses attributed to it are variable from year to year. Also, corn borer pressure is not evenly distributed along maize-growing regions, reflecting the variability of agro-climatology conditions existing in Europe and Spain. Therefore, the agronomic and economic performance of Bt maize versus its conventional counterpart is supposed to show spatial and temporal variability.

[8] Sustainable introduction of GM crops into European agriculture. SIGMEA is a specific targeted research project in the EC 6th FRAMEWORK PROGRAMME. Priority Policy Oriented Research [FP6-2002-SSP1 -]. Contract no.: 502981. SIGMEA started on 3 May 2004 and runs for 3 years.

3.2. Commercial release and adoption of Bt maize by Spanish farmers

On February 1997, the European Union authorised the cultivation of Bt maize (transgenic event Bt-176 of the company Syngenta). Following this approval at EU level, two commercial maize varieties derived from Bt-176 were inscribed by the company Syngenta in the Spanish Register of Commercial Varieties in 1998. The first plantings in Spain took place in the same year. Syngenta placed in the market enough seed to sow 20 000 ha of Bt maize in 1998, roughly 5% of the surface of maize in Spain. The evolution of the plantings and adoption rates in Spain since 1998 is summarised in Table 5. The distribution of the area among main Spanish Bt maize growing regions is also shown in the table.

Table 5: Evolution of Bt maize area in Spain and in the 3 main Bt growing regions

	Total area cultivated with Bt maize (hectares)							
Region	***1998***	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***
Castilla-La Mancha	4 572	3 282	2 648	872	3 751	7 681	8 197	7 957
Aragon	11 554	7 315	8 075	4 268	8 302	12 589	25 547	21 259
Catalonia	1 711	3 033	4 554	3 265	4 783	5 430	15 699	16 830
3 regions together	17 837	13 630	15 277	8 405	16 836	25 700	49 443	46 046
Rest of Spain	4 630	11 442	10 784	3 193	4 168	6 544	8 776	7 179
Total Bt maize Spain (ha)	**22 467**	**25 072**	**26 061**	**11 598**	**21 004**	**32 244**	**58 219**	**53 225**
	Adoption rates (Bt maize area/total maize area)							
Region	***1998***	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***
Castilla-La Mancha	8.70%	7.10%	5.80%	1.70%	7.80%	14.80%	14.90%	15.89%
Aragon	13.90%	12.40%	10.20%	4.30%	10.50%	14.30%	28.10%	31.38%
Catalonia	4.50%	9.30%	12.40%	7.40%	15.00%	13.00%	37.60%	43.17%
Rest of Spain	1.70%	4.60%	4.00%	1.00%	1.90%	2.20%	3.00%	3.65%
National adoption Rate	**5.00%**	**6.50%**	**6.10%**	**2.30%**	**5.50%**	**6.80%**	**12.14%**	**12.59%**

Source: Adapted from (MAPA, 2006, MAPA, 2005)

During the period 1998-2002 there were no additional authorisations of novel GM maize events (or any other GM crops) for cultivation in the EU. During this period Syngenta limited the amount of Bt-176 maize seed sold in Spain, and the surface planted with Bt maize in Spain did not increase significantly. This changed in 2003 when the EU approved for cultivation a new Bt maize (transgenic event MON-810 of the company Monsanto). New commercial Bt maize varieties derived from MON-810 were registered in Spain in 2004 and the surface cultivated increased, to peak at about 58 000 hectares of Bt maize in 2004 and 53 225 hectares in 2005, or 12-13 % of total maize cultivated area in Spain (Table 5).

By 2005 there were over 30 Bt maize commercial varieties available for Spanish farmers, the large majority based on the transgenic event MON-810, produced and commercialized by more than 10 local and multinational seed companies.

3.3. Methodological approach and sources of data

To obtain empirical evidence on the economic impact of Bt maize adoption at farm level, the approach selected was to design and conduct a survey of commercial maize growers in Spain, that took place in 2005. The use of direct surveys of farmers is considered by experts to be the most solid methodological approach when trying to estimate *ex post* economic impacts of GM crops and factors explaining adoption. Some socio-economic studies on GM crops are based on extracting data from comparative side-by-side field trials of GM and conventional varieties. However these trials are designed usually to maximize yields and do not reflect real management practices of commercial farmers.

The type of survey used was a farm-level survey. A questionnaire directed to commercial maize growers was specifically designed and to guarantee a reasonable rate of response, personal interviewing was selected as contact method. The nature of the questions, especially those related to economic data, requires also this contact method. Data obtained in the survey was then analysed with the appropriate statistical tools to identify differences between adopters and non-adopters of Bt technology in terms of farmers' gross margin (economic indicator), employed farm labour and welfare created (social indicator) and changes on pesticide use (indirect environmental indicator).

The selection of the Spanish regions to carry out the survey was based on the presence of Bt maize. Table 5 shows that the three main regions cultivating Bt maize in Spain are Aragon (21 259 hectares), Catalonia (16 830 hectares) and Castilla-La Mancha (7 957 hectares). Currently, these three regions together represent more than 85% of the total Bt maize area in Spain, averaging 75 % for the 1998-2005 period. Therefore the regions of Aragon, Catalonia and Castilla-La Mancha were selected for the survey. Within each region, the specific locations for the survey were selected on the basis of the presence of adopters of Bt maize. For this, secondary information was collected from various organisations with knowledge of the topic (farmers' cooperatives, academia and trade unions). The provinces selected (Figure 2) were Zaragoza (39% of the maize area cultivated in Aragon), Albacete (51% of the total maize area cultivated in Castilla La Mancha), and Lleida (75% of the total maize area cultivated in Catalonia).

The population (maize growers) was stratified into two separate subgroups - adopters and non-adopters of Bt technology. From each of these sub-groups simple random samples were taken in each province. In order to establish the size of the total sample (n=402 farmers), the study considered the population of Bt farmers in Spain consisting of approximately 4 800 Bt maize farmers in 2004. With this total sample size the data gathering worked with a degree of error lower than ± 5% over the total population, assuming a maximum indeterminacy (p=q=50%), and within a reliable 95.5%. A pre-coded questionnaire was tested on a pilot sample of farmers and the final survey of the target population took place during May and June 2005.

3.4. Impact of Bt maize on revenues and costs for Spanish farmers

GM crop adoption involves potential on-farm effects both on revenues and costs compared with the conventional counterpart. *A priori*, the farm-level profitability of a GM crop such as Bt maize is a function of some key variables such as:

- Differences in yield (Bt crops are expected to reduce yield losses attributed to pests)
- Differences in market price of the harvest
- Reduction in pest control costs (Bt crops are expected to reduce insecticide applications)

- Differences in seed price (GM varieties are more expensive than conventional counterparts).

Additionally, novel operating costs may be linked to the introduction of GM crops, for example, the recommended planting of refuges with non-GM plants in the case of Bt crops (for avoiding the appearance of resistance in pest populations). Also, a novel potential cost incurred by GM crop farmers in the EU will be the mandatory farm measures to ensure coexistence with non-GM crops (these measures are being discussed by Members States of the European Union)[9].

To estimate the on-farm economic impact of Bt maize adoption in Spain, the gross margins of farmers cultivating Bt maize or conventional maize were calculated and compared for the 2002-2004 period, based on survey's data. The survey produced data from a total 184 individual farmers declaring to grow only conventional maize ("conventional maize" group). A total of 195 farmers declaring to grow only Bt maize were surveyed for comparison ("Bt maize" group). The survey also identified a small group of 23 farmers who declared to cultivate both types of maize, but these were excluded from the analysis since economic information provided by these farms was aggregated and not segregated by maize type ("Bt +conventional maize" group)[10].

Table 6 illustrates the distribution of types of maize growers surveyed by province.

Table 6: Number and type of maize growers surveyed

	Province			
Types of maize growers	***Albacete***	***Lleida***	***Zaragoza***	***Total***
Conventional maize farmers	61	52	71	***184***
Bt maize farmers	42	66	87	***195***
Bt+conventional farmers	2	16	5	***23***
Total province	***105***	***134***	***163***	***402***

Impacts on revenues (yields and market prices)

To calculate gross margin differences, the first variable analysed was the difference in yields between Bt and conventional maize in Spain. Table 7 shows average yields and variance for Bt and conventional maize in 2002, 2003 and 2004.

9 See Commission Recommendation of 23 July 2003 on guidelines for the development of national strategies and best practices to ensure the coexistence of genetically modified crops with conventional and organic farming and COM (2006) Communication from the Commission to the Council and the European Parliament: Report on the implementation of national measures on the coexistence of genetically modified crops with conventional and organic farming.

10 The organic maize sector in Spain is currently very small (probably around 0.1 % of total maize production). No organic maize growers were found among sampled farmers.

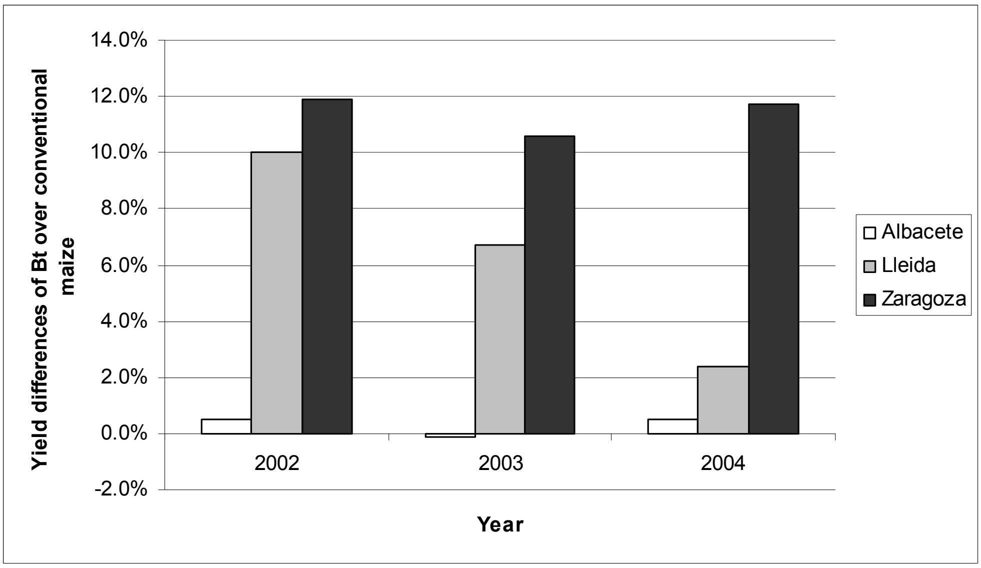
Table 7: Average yields for Bt and conventional maize (2002/2004)

	CONVENTIONAL MAIZE			BT MAIZE			BT/CONV.
Year	**Mean (tons/ha)**	**Variance**	**n**	**Mean (tons/ha)**	**Variance**	**n**	**% yield advantage**
2002	11.07	4.11	88	11.67	3.20	88	***5.4%***
2003	10.64	4.06	109	11.14	3.40	116	***4.7%***
2004	11.04	4.93	126	11.48	2.84	139	***3.9%***
2002/2004	**10.92**	**4.37**		**11.43**	**3.15**		**4.7%**

The results show that Bt maize had yield advantages over conventional maize in the 3 years studied (5.4% in 2002, 4.7% in 2003 and 3.9% in 2004). For the period analysed and at national level, the average yield increase attributed to Bt maize is estimated at 4.7 %. The variance of yields within Bt maize growers is smaller than that for conventional growers.

The yield increase obtained by Bt maize farmers in Spain presents, however, clear regional differences and (less marked) temporal differences (Figure 2). Differences in yield between Bt and conventional maize range from -0.1% in Albacete in 2003 to +11.9% in Zaragoza in 2002. Bt maize seems to perform differently in the 3 regions, and this variability could be explained by heterogeneity among farmers, differences in pest pressure (Qaim, et al., 2006), and the fact that Bt technology was not introduced yet in varieties suited for all regions (until 2003 there was only 2 commercial Bt varieties and the number currently is over 35).

Figure 2: Yield differences of Bt over conventional maize in Spain by year and province



Potential price differences in the price received by farmers for Bt or conventional maize were analysed using survey data. No statistical difference was found between the price received by Bt maize farmers or conventional maize farmers averaging 0.128 € per kilogram (Table 8).

Table 8: Harvest price (€/kg) received by surveyed maize farmers in Spain

TYPE OF MAIZE HARVESTED	MEAN	N	MEDIAN	STD. DEV.
CONVENTIONAL MAIZE	0.129	169	0.130	0.018
BT MAIZE	0.127	184	0.130	0.019
BT+CONVENTIONAL MAIZE	0.130	23	0.130	0.018
TOTAL	**0.128**	**376**	**0.130**	**0.018**

Impacts on costs at farm level

Pest control costs were analysed from using data from the survey on the number of insecticide applications against corn borer done by farmers using Bt or conventional maize. The survey also allowed the estimation of the average cost of an insecticide application (€21.10 per pesticide treatment and hectare), and the resulting calculations of pest control costs are summarised in Table 9. Bt maize farmers from the three provinces experienced savings in pest control costs (€9.5 per hectare in Albacete, €4.5 per hectare in Lleida and €20 per hectare in Zaragoza).

Table 9: Pest control cost of Bt and conventional maize farmers

	CONVENTIONAL MAIZE		BT MAIZE		CONV-BT
Provinces	Average number of insecticide applications against maize borer	Pest control cost (€/ha)	Average number of insecticide applications against maize borer	Pest control cost (€/ha)	Savings in pest control cost experienced by Bt maize farmers (€/ha)
ALBACETE	0.64	13.5	0,19	4.0	9.5
LLEIDA	0.21	4.5	0,00	0	4.5
ZARAGOZA	1.52	32.1	0,57	12.0	20.0

The additional seed cost incurred by farmers using Bt maize was estimated from the survey. GM seed developing companies usually recommend a "royalty fee" to distributors, yet the final price paid by farmers depends also on the ability to negotiate (presence and role of cooperatives, size of the farm, etc). Table 10 shows the seed cost for Bt or conventional maize farmers in Spain. Price differentials for Bt maize seeds varied between provinces. It should be noted that price differentials are highest in Zaragoza (where Bt maize gives the highest yield increase) and lowest in Albacete (where yield increases due to Bt maize are lowest).

Table 10: Seed costs (€/ha) for conventional and Bt maize farmers by province (2002-2004 average)

	CONVENCIONAL MAIZE FARMERS		BT MAIZE FARMERS		ADDITONAL SEED COSTS FOR BT MAIZE FARMERS (€/HA)
ALBACETE	MEAN	MEDIAN	MEAN	MEDIAN	
	172.61	169.80	179.58	175.00	**6.96**
LLEIDA(*)	MEAN	MEDIAN	MEAN	MEDIAN	
	164.88	175.13	193.67	N/A	**28.79**
ZARAGOZA	MEAN	MEDIAN	MEAN	MEDIAN	
	179.67	172.29	217.46	216.87	**37.79**
(*) DATA AVAILABLE ONLY FOR 2004					

3.5. Impacts of Bt maize on farmer's gross margin

Table 11 summarises the final economic balance of Bt maize on-farm and calculates the differences in gross margin obtained by Bt maize farmers in Spain compared with conventional maize farmers for 2002-2004. The results constitute the first empirical data on economic performance of a GM crop in the EU. The national average column is obtained as a weighted average combining all the variables in each region with the proportion of cultivated area of Bt maize represented by each region at national level in 2004, i.e. Albacete (17.28%); Lleida (36.55%) and Zaragoza (46.17%).

Table 11: On-farm economic balance of Bt maize in Spain and by province

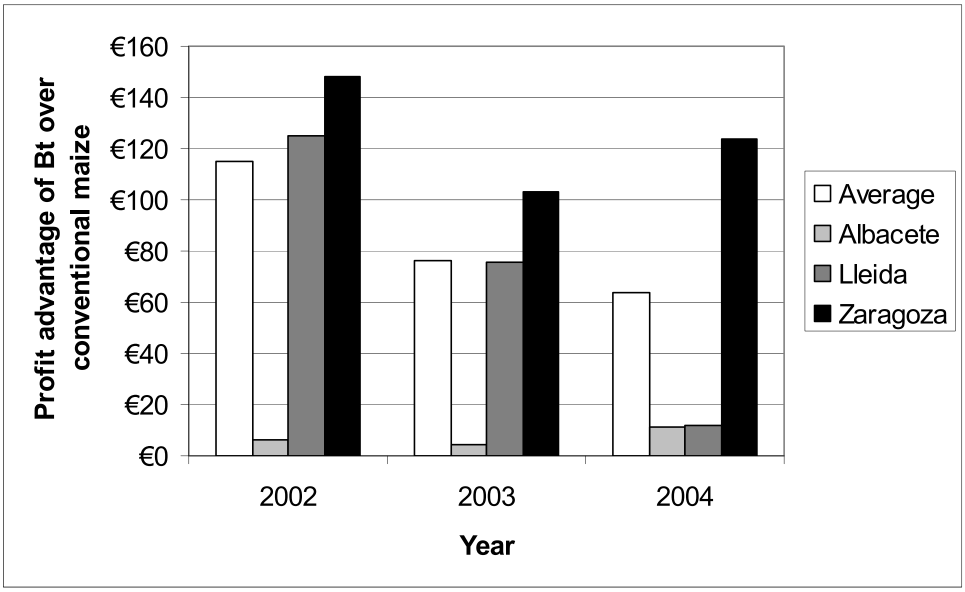
PERIOD 2002/04	NATIONAL WEIGHTED AVERAGE	ALBACETE	LLEIDA	ZARAGOZA
Yield increase (tons/ha)	0.78	0.04	0.73	1.10
Revenue increase				
Sales increase (€/ha)	101.52	4.77	95.23	142.71
Pesticide savings (€/ha)	12.5	9.50	4.50	20.05
Cost increase				
Seed cost increase (€/ha)	29.17	6.96	28.79	37.79
Gross margin difference (€/ha)	**84.84**	**7.28**	**70.90**	**124.90**

For the three growing seasons studied (2002-2004), farmers using Bt maize obtained higher gross margins than farmers growing conventional maize. Considering Spain on average, gross margin difference amounted to € 84 per hectare and per growing season. Putting this figure into context, a net increase of € 84 per hectare represents an increase of 12% over the average gross margin obtained by a maize farmer in Spain (CAP subsidies not included in revenues).

These benefits, however, vary widely in the three regions studied (Table 11), ranging from the highest gross margin differences in Aragon (€ 124.9 per hectare) to near average increases in Catalonia (€ 70.9 per hectare) or the small difference of 7.2 € per hectare in Albacete (Castilla la Mancha).

The variability in gross margin advantage for Bt maize growers is further illustrated by Figure 4. In fact, this variability mimics the variability found in agronomic yield increase (Figure 3), the key factor defining the economic balance, since the differences on GM seed prices, and pesticide saving costs are smaller.

Figure 3: Gross margin differences of Bt over conventional maize growers, by year and province (€/ha)



Farm level economic impacts in other Bt maize-producing countries

The main Bt maize growing country is the US, followed by Argentina, Canada and South Africa (James, 2005). To compare the on-farm economic impact of Bt maize in Spain with data obtained elsewhere, peer-reviewed publications were surveyed and found for the case of South Africa. For the US, no peer-reviewed articles were found, but governmental agencies' reports referring to the first years of adoption (1997-1999) are available. No data was found for Argentina or Canada.

South Africa authorized in 1998 the cultivation of yellow Bt maize which is used as animal feed and as an input in the food industry. In 2001, white Bt maize was authorised as well. White maize is the basic staple food in South Africa. Both Bt maize crops are developed to resist the African (*Busseola fusca*) maize stem borer. In 2005, South Africa cultivated about 85 000 hectares of white GM maize and 195 000 hectares of yellow GM maize (James, 2005).

Gouse et al. (2005) surveyed 33 large-scale yellow maize producers to gather data for the 1999/2000 and 2000/2001 production seasons. Four South African provinces where analysed. Farmers cultivating Bt maize achieved yield increases ranging from 7% to 12% more than conventional maize farmers. The yield advantage together with reduced pesticides costs resulted in income increases ranging from €19.2 per hectare to €119 per hectare. Table 12 summarizes compares the economic advantage/disadvantage obtained by farmers adopting Bt maize in Spain, South Africa and the US.

Table 12: Yearly average economic differences of Bt over conventional maize (€/ha)

Phenomenon	Indicator	Value		Source
Economic advantage/disadvantage	**Average economic advantage/disadvantage of Bt over conventional maize**			
		in Albacete (Spain)	7.28 €/ha	This case study
		in Lleida (Spain)	70.90 €/ha	This case study
		in Zaragoza (Spain)	124.90 €/ha	This case study
		in Mpumalanga-Dry land (South Africa)	37.60 €/ha	(Gouse, et al., 2005)
		in Mupmalanga-Irrigated land (South Africa)	68.00 €/ha	(Gouse, et al., 2005)
		in North West-Dry land (South Africa)	19.20 €/ha	(Gouse, et al., 2005)
		in Northern Cape- Irrigated land (South Africa)	119.00 €/ha	(Gouse, et al., 2005)
		in the US in 1997	37.00 €/ha	(Carpenter and Gianessi, 2001)
		in the US in 1998	-3.72 €/ha	(Carpenter and Gianessi, 2001)
		in the US in 1999	-3.56 €//ha	(Carpenter and Gianessi, 2001)
Note: Values for Albacete, Lleida and Zaragoza are averages for the three years period 2002-2004. Values in South Africa are referred to season 2001/2002.				

Gouse et al. (2005) also surveyed 368 small farmers in South Africa performing field trials of growing Bt and conventional white maize side by side. On average Bt maize had a large yield advantage over the conventional seeds but the authors could not carry out an analysis of the economic performance since GM seeds where freely distributed by seed companies to carry out the trials.

In the US, the evidence available is limited to the early years of adoption and points to very variable on-farm economic effects due to large differences in geographical incidence of corn borers. Carpenter and Gianessi (2001) reported that on average, Bt maize yields were higher than those of conventional maize during the 1997-1999 period. However, economic impact due to higher yields and small savings in pest control costs can be offset by higher GM seed prices, and Carpenter and Gianessi (2001) reported for 1998-99 lower income per hectare for Bt maize farmers compared with conventional maize farmers. A similar result was reported by Fernandez-Cornejo and McBride (2002) for the 1998 growing season. Hyde et. al. (1999) also found that on farm economic impact of Bt maize varied systematically with maize borer pressure in Indiana (USA).

What is the incentive then for adopting Bt maize in the US? Marra et al. (2003) have reviewed the role of risk, uncertainty and learning in the adoption of new agricultural technologies. They use the example of GM insect resistant crops (Bt crops) where uncertainty comes primarily from variable seasonal levels of pest infestations. They conclude that farmers with "high levels of absolute risk aversion" contemplate Bt maize as an attractive technology. Farmer advisers, extension educators and academic researchers suggested farmers to use Bt maize as "insurance" against crop losses in the long term. On the other side, market uncertainties, maize output prices, price paid for the technology (GM seeds) and seasons with low level infestations are factors of economic risk when deciding to adopt Bt maize.

Our empirical analysis shows indeed that Bt maize in Spain reduced yield variance (in addition to increasing yield average) therefore reducing uncertainties about final production. Also, in our survey we included direct questions on farmer's reasons for adopting Bt maize. The results (Table 13) show that risk aversion is the reason most frequently cited by adopters.

Table 13: Reasons invoked by farmers in Spain for adopting Bt maize

ORDER OF IMPORTANCE	REASONS FOR ADOPTING BT MAIZE	MEAN	STD.DEV
1	Reduction of risk of losses due to maize borer	4.61	0.602
2	Higher yields	4.44	0.795
3	Ensures better quality of harvest	4.27	0.939
4	Makes me feel more safety/It guarantees me more security	4.24	0.949
5	It guarantees a greater income	4.20	0.963
6	It facilitates my work being at technology that makes cultivation easier	3.95	1.332
7	Saving costs in plant health products	3.65	1.439
8	The technician or technicians that assist that I have consulted have recommended its use	3.48	1.486
9	My regular seed supplier recommended me its use	3.44	1.593
10	Environmental impact in my farm is lower because I can decrease the application of pesticides	3.29	1.372
11	It makes me feel I am at the forefront of biotechnological progress	3.24	1.369
12	All farmers around my zone are using it	2.94	1.357
	N= 194		

3.6. Social impacts of Bt maize adoption in Spain

Impact on dedication to farming and on off-farm economic activities

One of the objectives of the EU rural development policy is to encourage farmer's diversification of economic activities[11]. Off-farm income is generally more stable than that obtained from farming activities (Nehring, et al., 2005). Surveyed farmers in Spain were asked about their dedication to farming. Results show that most individuals are full time farmers (82.75%). No statistical relationship was found between the type of maize grown (conventional, Bt or Bt+conventional) and the dedication to farming activity. Additionally, farmers carrying out off-farm work were not statistically associated to the type of maize they were cultivating. A similar result was obtained by Fernandez-Cornejo and McBride (2002) analyzing the effect of GM maize on increased off-farm work in the US .

The most widely adopted GM crop world-wide, herbicide tolerant soybean (HT soybean) has, however, been associated to increased off-farm income of adopter farmers in the USA (Fernandez-Cornejo, et al., 2005). The simplification of weed management regime of the soybean crop allowed by the use of HT varieties results in increased free time for adopter farmers.

11 Council Regulation (EC) No 1698/2005 of 20 September 2005 on support for rural development by the European Agricultural Fund for Rural Development.

Impact on employed farm labour

The adoption of Bt maize has no impact on the amount of farm labour employed, according to our survey. Table 14 illustrates different types of employed farm labour (paid or non-paid) in the maize farms surveyed in Spain. The analysis of variance does not find statistical relationships between this variable and the type of maize adopted.

Table 14: Paid employed farm labour in surveyed maize farms in Spain

		NUMBER OF PERMANENT WORKERS (NON-FAMILY)	NUMBER OF PAID WORKERS FROM THE FAMILY	NUMBER OF WORKERS IN PEAK PERIODS	TEMPORAL WORKERS HIRED IN PEAK PERIODS (IN NUMBER OF DAYS WORKED)
CONVENTIONAL MAIZE GROWERS	MEAN	0.12	0.09	1.27	7.37
	N	184	184	183	174
	STAND. DEV.	0.58	0.36	3.58	17.69
BT MAIZE GROWERS	MEAN	0.16	0.11	1.72	13.18
	N	194	194	194	178
	STAND. DEV.	0.64	0.44	5.29	40.77
BT+CONVENTIONAL MAIZE GROWERS	MEAN	0.00	0.09	1.74	8.91
	N	23	23	23	22
	STAND. DEV.	0.00	0.29	6.24	22.72
TOTAL	MEAN	**0.13**	**0.10**	**1.52**	**10.23**
	N	**401**	**401**	**400**	**374**
	STAND. DEV.	**0.60**	**0.39**	**4.65**	**31.16**

Regarding family help in farming most farmers use it either very occasionally or never (see Table 15). Simple test analysis on the table does not show statistical significance for the relationship between occurrence of family help and type of maize growers. Both types of maize growers are a part of families that have, in principle, the same chances to obtain off-farm income.

Table 15: Family help in the farm according to the type of maize growers

	TYPES OF MAIZE GROWERS			
HELP FROM FAMILY MEMBERS	CONVENTIONAL MAIZE GROWERS	BT MAIZE GROWERS	BT+CONVENTIONAL MAIZE GROWERS	TOTAL
ALWAYS	24	25	5	**54**
%	13%	13%	22%	**14%**
FIXED PLUS SEASONAL	8	15	0	**23**
%	4%	8%	0%	**6%**
SEASONALLY	70	72	6	**148**
%	39%	38%	26%	**38%**
WITHOUT HELP	78	79	12	**169**
%	43%	41%	52%	**43%**
TOTAL	180	191	23	**394**

Adoption of Bt maize and farm size in Spain

Surveyed maize farms in Spain are quite heterogeneous in size. Our survey shows that the adoption of Bt maize in Spain is not statistically related to farm size. Table 16 summarises the farm size distribution for the three types of maize growers.

Table 16: Farm size distribution (ha) according to type of maize cultivated

FARM CULTIVATED AREA TYPE OF MAIZE	Mean	N	Std. Deviation
Conventional maize	43.43	184	60.73
Bt maize	47.31	195	64.36
Bt+conventional maize	39.57	23	30.63
Total population surveyed	45.09	402	61.19

There is a possibility that this situation changes when the introduction by the Spanish government (following EU guidelines) of mandatory technical measures for GM crop farmers, to ensure coexistence with non-GM crops. This will be a novel cost to account in the balance of Bt maize in Spain, as discussed in other section of this report, and larger farms are likely to cope better with this novel measure and to implement it at lower unitary cost.

Distribution of economic welfare created by Bt maize adoption in Spain

Bt maize belongs to the so-called first generation of GM crops which aim to provide higher production efficiency at the farm level. Therefore direct benefit for consumers could be derived only from a reduction of the market price. We have already shown (Table 8) that the prices received by farmers in Spain for Bt or conventional maize are the same. In Spain, Bt maize grain production is enterily sold for animal feed production. Our survey findings match with Spanish feed industry claims that they have not benefited directly from the introduction of Bt maize in Spain by a reduction in raw material's cost, since there was no difference in the prices they had to pay for Bt or conventional maize (de Saja, 2006).

Therefore the economic welfare resulting from the adoption of Bt maize in Spain is basically shared by farmers and seed companies. In the latter we include the seed developer, seed producers as well as seed distributors. Based on the on-farm economic balance derived from our survey, Table 17 shows the distribution of the welfare created by Bt maize in Spain for the three Spanish provinces studied. The largest share of welfare (74.4 % on average) went to Bt maize farmers and the rest went to the seed companies (25.6% on average).

Table 17: Distribution of the welfare created by Bt maize in Spain during 2002-2004 (per hectare and year)

2002/04	Weighted average (€/ha)	%	Albacete (€/ha)	%	Lleida (€/ha)	%	Zaragoza (€/ha)	%
Total welfare	114.01	100.0	14.24	100.0	99.69	100.0	162.68	100.0
Welfare to seed companies	29.17	25.6	6.96	48.9	28.79	28.9	37.79	23.2
Welfare to farmers	84.84	74.4	7.28	51.1	70.90	71.1	124.90	76.8

A similar analysis of distribution of welfare created by Bt maize is only available for South Africa, based on the on-farm economic data of Gouse et al. (2005) described previously, and is summarised in Table 18. As described earlier, these figures correspond to the survey of 33 large-scale maize producers for the 1999/2000 and 2000/2001 seasons. By comparing Tables 17 (Spain) and in Table 18 (South Africa) one can see that roughly a 75% of welfare gains to farmers and a 25 % to seed companies defines the most common situation. The factor most directly affecting the welfare ratio farmers/seed companies is the local variations in GM seed price.

Table 18: Distribution of welfare created by Bt maize in South Africa (per hectare and year)

	Mpumalanga Dry land (€/ha)	%	North West Dry land (€/ha)	%	Mpumalanga Irrigation (€/ha)	%	North West Irrigation (€/ha)	%
Welfare to farmers	39,2	73,4	20	75	70,8	77,3	124,2	91,4
Welfare to seed companies	14,2	26,6	6,7	25	20,8	22,7	11,7	8,6
Total welfare	53,3	100	26,7	100	91,7	100	135,8	100

Source: Adapted from Gouse (2005)

3.7. Environmental impacts of Bt maize in Spain

Any innovation that results in changes in the way a crop is managed may have an impact on the environment. There is scientific consensus that the impact of the introduction of GM varieties has to be analysed case-by-case depending on the nature of the genetic modification and the changes in field management prompted by the new characteristics of the variety (herbicide tolerance, insect resistance, etc) (FAO, 2004).

In particular, Bt crops can potentially reduce the environmental pressure of intensive agriculture (through less spraying of insecticides) but could also have an impact on non-target insect species (since the GM plant produces its own insecticide) that must be evaluated. This section attempts to shed light on these potential environmental effects of Bt maize in Spain. Data on changes in use of pesticides due to Bt maize cultivation comes from empirical evidence gathered in our survey. Effects on non-target organisms and other potential environmental impacts will be reviewed based on existing scientific literature.

Reduction of insecticide treatments due to Bt maize adoption

We have compared the use of insecticides by Bt and conventional maize farmers in Spain for controlling maize borers. Insecticide control of maize borers is difficult because insecticide sprays are effective only in the narrow time span between egg hatch and larvae boring into stems. The lack of effectiveness and additional cost is the reason why many maize farmers do not spray insecticides specifically for controlling corn borers and assume the yield losses, but precise figures with statistical relevance were missing.

In Table 19 we present the number of insecticide treatments given by Spanish farmers to control maize borer, according to the type of maize grown. We found that 42 % of conventional maize growers surveyed do not use insecticides at all for controlling corn borers, and this figure increases to 70% for Bt maize growers. 21 % of conventional maize farmers give two or more treatments per year, and this figure is reduced to 2% of Bt maize growers.

Table 19: Insecticide treatments against maize borer given by surveyed farmers

Number of treatments per year	Conventional maize growers (Number and %)	Bt maize growers (Number and %)
0	77 (42%)	136 (70%)
1	68 (37%)	56 (29%)
2	29 (16%)	3 (2%)
3	8 (4%)	0 (0%)
4	2 (1%)	0 (0%)
Total	**184 (100%)**	**195 (100%)**

On average, conventional maize growers did 0.86 treatments/year compared with 0.32 treatments/year of Bt maize growers (see Table 9 presented in section 3.4). This reduction is modest in absolute terms, because we have shown that the conventional way of maize borer control that Bt maize is replacing is not based on heavy insecticide use due to its inefficacy.

Similar analyses in the USA showed that adoption of Bt maize did not reduce pesticide use significantly because few farmers used pesticides on their conventional maize crops (Marra, et al., 2002). Gouse et al. (2005) found that Bt maize in South Africa reduced pesticide use for the large 33 commercial farmers analysed. However, Gouse's paper does not indicate the size of such reduction neither in number of sprays nor in quantity of pesticide used.

Impact of Bt maize on non-target organisms

Insect-tolerant Bt crops (basically Bt maize and Bt cotton) have been used now for over a decade world-wide. Bt crops may be beneficial in comparison to conventional crops if they enable the management of insect pests in a more specific way than conventional insecticides. On the other side, the widespread adoption of the Bt crops may result in effects on non-target fauna and soil micro-organisms due to the pesticide toxin expressed by Bt genes in all parts of the plant. (Ammann, 2005, GM-scientific-panel, 2004) .

Dozens of peer-reviewed papers have been published in the last years examining the effects of Bt crops on non-target species abundance and biodiversity. Experiments on the effect on non-target species have been conducted in laboratory or glasshouse environments, in field and semi-field situations. Experiments on the specific effects of Bt maize to non-target fauna in field and semi-field conditions in Spain have been conducted and published.

For the case of Bt maize in Spain, a post-marketing monitoring plan, including a environmental risk assessment programme, sponsored by the Ministry for the Environment is being conducted by public research institutions since 2000. One of the objectives is to assess the potential impact of Bt maize on non-target arthropods. The abundance and activity of predatory fauna has been measured in a farm-scale analysis over three years and in different growing areas of Bt maize in Spain. The results published last year by De la Poza et al. (2005), show that no detrimental effect of farm scale Bt maize was observed on any predator taxa or on the whole functional group, suggesting that Bt maize is compatible with the naturally occurring predatory fauna that contributes to biological control of pest populations in maize fields.

This outcome is in agreement with evidence coming from over 50 of such studies world wide that has been reviewed by a group of experts in Integrated Pest Management from the Swiss Federal Research Station for Agro-ecology and Agriculture, in a paper published in Nature Biotechnology (Romeis, et al., 2006). The main conclusion is that the abundance and activity of parasitoids are similar in Bt and non-Bt crop fields, while the use of insecticides usually results in negative impacts on non-target fauna useful for biological control. Such conclusion, however, cannot predict the effect of other insecticidal proteins different from Bt toxin if ever incorporated into GM crops. The authors also recommend that researchers take greater care when designing experiments such as the results are relevant for field conditions, and that conventional pest management practices should be considered as the base line for risk assessment of Bt crops. Finally the authors conclude that since Bt technology does not harm non-target organisms and in some crops reduces the use of insecticides, it can contribute to Integrated Crop Management strategies with a strong biological control component.

Another review of 13 longer-term field studies on the non-target effects of Bt maize and cotton in the US and Australia was published last year in Environmental Entomology (Naranjo, et al., 2005). Authors conclude that these longer-term studies show the highly selective nature of Bt toxins used in Bt crops. Minor changes in the abundance of a few non-target taxa were documented but almost all these effects were explained by expected changes in target pest populations. Many studies documented that the alternative use of broad-spectrum insecticides was many times more damaging to non-target species.

The GM science review panel of the UK government, has also reviewed the available scientific literature on this topic, and has concluded that scientists agree that negative effects may happen but they do not agree about the chances for this to happen and that no significant adverse effects have been identified so far (GM-scientific-panel, 2004).

Other environmental impacts: development of resistance to Bt toxin in populations of pests

The monitoring programme designed by the Ministry of the Environment in Spain also deals with the issue of the development of resistance in corn borer populations to the Bt toxin. Since the Bt toxin is considered an environmentally-friendly insecticide (it is authorised for use in organic farming), the potential development of resistant pests is regarded as the loss of an environment-friendly technology apart from the obvious economic consequences associated.

Current resistance management strategies for Bt maize are based on the planting of a "refuge" of non-GM maize around the Bt maize fields in order to maintain a population of insects that is not under pressure to evolve resistance to Bt toxin. This population would mate with eventual resistant insects nearby, therefore making the offspring remain sensitive to Bt toxin. The "refuge" strategy design is given to Bt maize farmers in Spain as part of a code of good practice elaborated by seed companies and maize producers associations.

A resistance monitoring programme has been established by the Spanish Ministry for the Environment and carried out by public research institutions. Data released after 5 years of commercial Bt maize plantings (1998-2003 period) did not find an increase in resistance for corn borer populations sampled in Spain (Farinos, et al., 2004). However the researchers argue for the need to maintain the systematic monitoring activity more years.

Gene flow

Out-crossing to wild relatives, while being an important environmental issue for some GM crops, is not an issue for maize as no wild relatives are established in Europe (Ellstrand, et al., 1999). Some cross-pollination of Bt maize and conventional maize fields may occur in Spain since cultivation does not take place in a closed environment. While this is not an environmental issue, since only Bt maize varieties deemed safe for human health and environment are approved by the EU, the phenomenon may have economic and social consequences due to the labelling provisions for GM crops in the EU. These socio-economic issues are related to the so-called *coexistence* between the GM and non-GM agricultural varieties in Europe. How *coexistence* is regulated in the EU and its socio-economic impact is discussed in the next Chapter on future developments and impacts of GM crops in Europe.

4. Possible developments and impacts of GM crops in the EU

4.1. Potential economic effects of new GM crop adoption: *ex ante* studies

Ex ante evaluations deal with forecasting the economic impact of GM crops, at farm or aggregate level, before they are actually adopted. Evaluations of this kind have a strong modelling component and a number of parameters have to be estimated in *ex ante* studies. In particular, yield effects and cost reductions at farm level have to be estimated from experiences in field trials and/or commercial experience in other countries. This research is particularly relevant for the European Union, where GM crops have not yet been adopted (except for Bt maize in Spain). Sensitivity analysis of the main parameters is always fundamental to the soundness of this type of evaluation.

During the last years *ex ante* evaluation of the potential economic impacts of adoption of new GM crops by the European Union farming sector has attracted the attention of researchers. There is a small but growing number of published *ex ante* studies addressing the potential economic impacts of GM crops not yet approved for commercial cultivation by EU farmers. Below is a summary of these publications.

Desquilbet et al. (2001) evaluated the benefits derived from the potential adoption of herbicide-tolerant (**HT) rapeseed in France**. A survey was done to estimate weed control costs of farms growing conventional rapeseed. For the HT rapeseed variety, the estimation was built using data from HT rapeseed field trials carried out in France. For the baseline scenario the estimated rate of adoption of HT rapeseed by French framers was 75 % of farmers. With this adoption rate farmers would save € 24 million of weeding costs per season. The total gains from current 0% adoption to the 75% adoption of HT rapeseed in France were estimated at € 38 million per season.

May (2003) analyzed *ex ante* the economic consequences for **UK farmers of a potential adoption of HT (herbicide tolerant) sugar beet.** Assuming that all UK sugar beet growers adopted HT sugar beet, average savings in weeding costs were estimated at € 217 per hectare and year or € 33.5 million a year. Estimations were based on a complete cost analysis, using data mainly from different published sources such as the British Sugar annual national surveys.

Another peer-reviewed article by Demont and Tollens (2004) studied *ex ante* the welfare derived of introducing **HT sugar beet in the EU** and its distribution between different economic agents/regions. A spatial model was used in which the rate of adoption of HT sugar beet in the EU was assumed to be half the observed rate of HT soybean adoption in the US. This adoption rate was then applied to all the producer regions covered in the study (EU and rest of the World-ROW). The global accumulated welfare created was € 1.150 million after five years of adoption. Welfare created was shared by ROW (53%), the EU sugar beet growers (30%) and technology developers/seed suppliers (17%). Consumers do not capture gains using these assumptions.

Gómez-Barbero and Rodríguez-Cerezo (2005) analyzed the **potential adoption of Bt cotton in the Andalusia region (Southern Spain)**. A survey of 830 farmers across cotton production areas in Andalusia showed that 58% of the responding farmers know about GM Bt cotton. Within this group, 95% of the farmers were willing to grow Bt cotton varieties. Regarding the on-farm economic impact resulting from a potential adoption, the assessment is that savings on direct pest control costs will be achieved by reducing the number of insecticide treatments. This analysis was applied to a representative Andalusian cotton farm, where a reduction of 2.6 insecticide treatments per year was estimated. This would result in a costs saving of € 148.2 per hectare.

All these *ex ante* studies predict positive economic effects in the case of GM technology adoption. Positive effects come from a reduction of cultivation costs (weed and/or pest management costs). *Ex ante* results should be interpreted properly since they are based on many assumptions. The sensitivity of the results (farmers' gross margin, economic welfare gains) to variations in key parameters of the models (i.e. adoption rates or GM seed prices) has to be clearly documented. However, they are the only analytical tool available in the EU situation where no adoption has occurred so far other than Bt maize.

Ex ante analyses of the aggregate economic impacts of introducing specific GM crops in EU agriculture should also consider the novel regulatory framework on labelling and traceability of GMOs and derived products that became operative in 2004. A main objective of the new EU regulatory framework is to provide EU consumers with the possibility to differentiate (via labelling) and choice products derived or not from GM crops. This introduces issues such as possible market segmentation, price differentials, and novel costs for identity preservation and labelling/traceability. Similar frameworks are developed or being developed in other world areas.

Very few aggregate studies have yet modelled these issues when looking at the impacts of introducing a new GM crop into agriculture. One example is the evaluation of the possible introduction of GM wheat into US agriculture, performed by Johnson et al. (2005). Although the US regulations currently do not differentiate between GM or conventional products, the arrival of a GM crop for direct food use and as significant as wheat prompted the applicant company to suggest its introduction in farming together with a system of identity preservation. Johnson et al. (2005) assumed that introduction of GM wheat will create two significant market segments: one composed of non-GM wheat consumers and another of consumers who are indifferent to whether the commodity is of GM origin or not. Some crucial parameters (yield effects, on farm costs savings) of the wheat sector model run by Johnson et al. had to be assumed due to the lack of experience with commercial GM wheat cultivation. The authors assumed a 1% tolerance threshold for the presence of GM wheat in conventional wheat. The results show that producers and consumers of non-GM wheat bear the extra costs of segregation and identity preservation. These costs are substantial and depend mainly on the tolerance threshold considered. For the base scenario of the model, these costs outweigh the economic benefits derived from the introduction of GM wheat, resulting in a small net economic welfare loss at global level. The distribution of the welfare effect is highly dependent of wheat prices, but in all price scenarios, consumers who are indifferent to the origin of the wheat get the benefit of paying lower market prices. Consumers of non-GM wheat suffer losses because of the segregation costs. The authors estimate that the majority of non-GM wheat consumers will be outside the US, therefore losses will be essentially for foreign consumers.

In addition to labelling and traceability developments, in the case of the EU regulatory developments also include the novel concept of *coexistence* between GM and non-GM agriculture. The legal development of this concept has taken place so far only in the European Union and its definition and implications in the socio-economic balance of GM crops is presented in the next section.

4.2. Ensuring coexistence between GM and non-GM crops in the EU: economic impacts

When examining the economic balance and the adoption process of GM crops in the EU, a new element has to be introduced: the costs incurred in order to ensure coexistence with non-GM crops. The concept of coexistence stems from the decision by the EU that all marketed products containing more than 0.9 % GMOs should be clearly labelled, what applies also to harvest. The possibility of adventitious presence of GM material in non-GM harvests cannot be dismissed and can have economic consequences for farmers affected (if the need for labelling means less price for the harvest or lack of buyers).

Novel technical and organisational measures during crop production may be necessary to ensure coexistence. In 2003, the European Commission published a recommendation on guidelines for the development of national strategies and best practices to ensure the coexistence of GM, conventional and organic crops (2003/556/EC). The guidelines recommend that *those farmers bringing in the innovation into a region should be the ones taking measures and changing practices if needed* to ensure coexistence. The majority of EU Member States drafting coexistence rules have thus targeted GM crop farmers as the ones taking the measures (if necessary) and incurring the costs.

Will coexistence costs outweigh the gains in farmer's gross margin forecasted by *ex ante* studies or demonstrated in *ex post* studies in Spain? Quantification of coexistence costs for a number of GM crops in Europe (crop and seed production of maize, sugar-beet and cotton) is performed in a recent report coordinated by the European Commission's JRC (see Messéan, et al., 2006). For the case of maize, the results show that the economic consequences of coexistence arise when the GM maize grower has to introduce mandatory isolation distances (and mandatory buffer strips) between his GM maize plot and a neighbouring conventional plot. This is an opportunity cost that amounts to the difference in farmers´ gross margin between GM maize and the alternative crop planted in these isolation distances, which most likely will be conventional maize. As shown in the previous section, this difference is empirically estimated in Spain (for the period 2002-2004) at an average of €84 per hectare at national level. In addition to this opportunity cost, mandatory isolation distances or buffer strips have a direct effect due to the need to source inputs (seeds) and organise plantings for two crops instead of one.

Coexistence costs may also arise downstream the food chain, in the grain storage, transport and processing steps where the possibility of commingling cannot be excluded. We have already described that in the case of Bt maize in Spain, food industry has implemented a strict segregation system to ensure that starch factories and other facilities dealing with maize for human consumption (i.e. sweet maize or pop-corn maize) use only non-GM maize harvests. We have no empirical data on the cost of such segregation system for food industry in Spain or on the repercussion on prices.

New socio-economic issues, liabilities and compensation

Finally, there is the issue of liability and compensation costs to cover those farmers growing non-GM crops that could be affected economically by adventitious presence of GM material in their harvests. Most socio-economic experts agree in that the issue is a rather complicated one for theoretical discussion (how to design compensation funds, lack of insurance products suited for this purpose, directed, civil responsibility, etc). EU Member States are currently studying their options in this field. Further layers of theoretical complication can be added if one considers the possibility of cross-border gene flow between Member States with different legal regimes for civil liability and compensation.

In Europe there is very little practical experience, other than Bt maize cultivation in Spain, to understand how big this issue may become for GM crop adoption. Currently there are no available public official statistics in Spain on the number of complaints from farmers or on the economic assessments of the possible damage. The non-GM maize sector (over 500,000 ha) do not seem too concerned since feed industry buys at equal price GM and non-GM harvests. A few cases from organic maize farmers in Spain have been reported by media and NGOs, and competent authorities have questioned the sampling and detection methods used by complaining farmers. The organic maize sector in Spain is currently very small (around 0.1 % of total maize production).

What seems clear is that future adoption and impacts of GM crops in Europe largely depends on how these issues of coexistence and responsibility are finally addressed and resolved.

5. Summary and Conclusions

Adoption rates of GM crops in EU agriculture

- GM crops have a significant share of four major crops world-wide: soybean, cotton, maize and oilseed rape
- The rate of adoption of GM crops in EU agriculture is very small compared with other large agricultural producing regions. Only one GM crop (Bt maize) is currently authorised for cultivation in the EU. This crop has been adopted significantly only in one EU Member State.
- In contrast, the EU is the world's largest importer of GM crops, mostly for animal feed. The EU imports annually over 15 Million tonnes of soybean, the majority of which is GM. The EU also imports 2-3 Million tonnes of maize annually for feed purposes with a significant proportion being GM maize.

Impacts of the adoption of Bt maize: the case of Spain

- Bt maize was introduced in Spain in 1998 and the current adoption rate (2005) represents 13% of national maize cultivated area . Adoption is unevenly distributed between Spanish regions. Regions with high pest pressures such as Aragon or Catalonia have adoption rates over 30 and 40 % of maize cultivated area, respectively.

- The socio-economic impact of the introduction of Bt maize was studied for the 2002-2004 period on 3 Spanish regions, representing 85 % of the Bt maize area. This is the first empirical study on economic performance of a GM crop in the EU.
- Differences in revenues
  - Bt maize farmers showed a consistent increase in yield compared with conventional maize farmers. Moreover, Bt maize farmers experienced a reduction in the seasonal variation of yields. The average yield increase (2002/04) for Spain is 4.7%, yet with clear regional variations. The prices received by farmers for the Bt or conventional maize harvests are identical.
- Differences in production costs
  - Bt maize seeds are more expensive than conventional ones yet with some regional differences. Bt maize growers spent less in pest treatments than conventional growers.
- Differences in final gross margin for farmers
  - Farmers using Bt maize obtained higher gross margin compared with farmers growing conventional maize, during the 2002-2004 period. Considering Spain on average, gross margin difference amounts to 85 euros/hectare per growing season, an increase of 13% over the average gross margin obtained by a maize farmer in Spain. These benefits, however, vary widely in the three regions studied, ranging from the highest gross margin differences in Aragon (€ 125 per hectare) to near average differentials in Catalonia (€ 71 per hectare) or very small differentials (€ 7) in Castilla la Mancha.
  - Costs incurred by GM crop farmers to ensure coexistence with conventional crops have not been accounted for, since such measures are still under debate by the Spanish government and not necessarily applied by Bt maize growers. Once these measures become mandatory, the final gross margin differentials of Bt maize may be reduced..

- Social effects: off-farm income and total farm labour

  - Bt maize adoption does not result in an increase of off-farm income of adopting farmers in Spain. The same has been found in other countries. Other 1st generation GM crops such as HT soybean are associated to higher off-farm income due to the significant simplification of crop management they provide.
  - Bt maize adoption does not result in an increase of on farm employed labour in Spain. Both types of maize grower use it either very occasionally or never and there are no differences between Bt and conventional maize growers.

- Welfare created and distribution between economic agents
  - The surplus welfare created by Bt maize adoption in Spain is captured mainly by Spanish farmers adopting Bt maize (roughly 75 % of the benefit) followed by seed companies (about 25 % of the welfare). Other sectors such as feed industry or final consumers do not capture economic benefits since market prices of maize have not changed. This pattern of welfare distribution is similar to those found for other "1st generation" GM crops world-wide.
  - Maize farms are quite heterogeneous in size in Spain. However, the size distribution of Bt maize adopting farms is not different from that of non-adopting farms.

- Environmental effects: reduction of insecticide use
  - Corn borers are not efficiently controlled by insecticides, yet some farmers do spray for controlling these pests. 58 % of Spanish conventional maize farmers spray insecticides for controlling corn borer, this figure being reduced to 30 % among farmers using Bt maize. Conventional maize growers in Spain did 0.86 insecticide treatments/year on average for controlling corn borer, vs 0.32 treatments/year done by Bt maize growers.

- Environmental effects: impacts on non-target organisms and development of resistant pest populations

  - No detrimental effect of farm scale Bt maize cultivated in Spain was observed on non-target arthropods activity and abundance, according to research commissioned by the Spanish Ministry for the Environment and performed by public institutions.
  - This is also the outcome of many studies on Bt crops world-wide showing that conventional insecticides have a far larger impact on beneficial insects than Bt crops. Bt technology is now regarded as a potential tool in Integrated Pest Management strategies.
  - Data released after 5 years of commercial Bt maize plantings (1998-2003 period) did not find an increase in resistance for corn borer populations sampled in Spain. However the researchers argue for the need to maintain the systematic monitoring activity for longer periods.

Likely economic impacts of adoption of other GM crops by EU farmers

- A very limited number of GM crops is yet authorized for cultivation or in the regulatory process in the EU, compared with other world agricultural areas.

- In the short-medium term EU farmers may adopt GM crops for feed or industrial (including biofuels) uses rather than for food use. Food industry in Europe is reluctant to use GM varieties as raw materials

- *Ex ante* evaluation of the socio-economic impacts of adoption by EU farmers of GM crops currently cultivated elsewhere predicts positive increases in gross margins for European farmers adopting the technology. Increase in gross margin comes mainly from a reduction of cultivation costs (weed and/or pest management costs). This analysis has been performed, among others, for herbicide tolerant rapeseed (France) and sugar-beet (UK, EU) as well as for Bt cotton (Spain).

- Economic welfare created by new GM crop introduction may be offset by novel costs associated to market segmentation, identity preservation. It is very difficult to model *ex ante* the amount of such costs and its distribution between economic agents. One of the key parameters affecting these costs is the tolerance thresholds fixed for differentiation of GM and non-GM products.
- Finally, when examining future adoption and impacts of GM crops in the EU, a new element has to be introduced: the costs incurred in order to ensure coexistence with

non-GM crops. EU Member States are have targeted GM crop farmers as the ones taking the measures (if necessary) at farm level. A similar framework for coexistence directed to GM crop farmers is not in place in other areas of the world where GM crops are cultivated, and opens new questions for the process of adoption of GM crops by EU farmers and its economic balance.

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