Fifteen Years of Genetically Modified Crops in Argentine Agriculture

Eduardo J. Trigo

November 2011

The present study was financed by the Argentine Council for Information and Development of Biotechnology - ArgenBio

About the author:

Dr. Eduardo J. Trigo is a Senior Researcher with the FORGES Foundation and Grupo CEO, both institutions focusing on the provision of research and advisory services to the agricultural sector. The author wishes to thank Dr. Eugenio J. Cap, Director of the Institute of Economics and Sociology of INTA, for his contributions, suggestions and comments; as well as Federico Villarreal, Associate Researcher with the FORGES Foundation, for his contribution to developing this document.

About ArgenBio:

ArgenBio (Argentine Council for Information and Development of Biotechnology) is a non-profit organization whose mission is to disseminate information on biotechnology, contributing to its understanding through education and promoting its development.

This is an English version of the original paper written in Spanish

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Argentina is one of the leading countries in the use of genetically modified crops in agriculture, with more than 22 million hectares dedicated to soybeans, maize and cotton crops using this type of technologies. The process of adoption of GM technologies began in 1996 with the introduction of glyphosate herbicide-tolerant soybeans, and has evolved until the present with an almost unprecedented adoption dynamics at world scale that has made GM technologies to be now used in nearly all soybeans crops, in 86% of maize crops, and 99% of cotton crops. This process has implied cumulative gross benefits for Argentina amounting to US$ 72,645.52 million. Out of that total figure, US$ 65,435.81 million accounted for herbicide-tolerant soybeans, US$ 5,375 million to (Bt) insect-resistant and herbicide-tolerant maize (single and combined events) and US$ 1,834 million to insect-resistant and herbicide-tolerant cotton (single and combined events).

Additionally to the above-mentioned benefits, it has also been estimated the impact that GM technologies have had in terms of job creation, between the time of their introduction and the last crop season (2010/2011). According to estimates made within the 15-year period after their adoption, total jobs created by the Argentine economy that could be attributed to such technologies would be over 1.8 million.

The above-mentioned benefits have been estimated on the basis of a mathematical model developed by INTA (SIGMA), which uses information obtained from the Technological Profile Study of the Argentine Agricultural Sector, supplemented by information from MAGyP, ArgenBio, INDEC and FAO. The model allows the calculation of gross benefits, as well as the manner in which these benefits have been distributed among the various productive players and the Government. In this respect, in the case of herbicide-tolerant soybeans, the gross value of benefits obtained from the reduction of production costs was US$ 3,518.66 million, and from the expansion of planted area was US$ 61,917.15 million. Regarding the distribution of such benefits, 72.4% went to farmers, 21.2% to the National Government –through export taxes and other duties-, and the remaining 6.4% to technology suppliers (seeds and herbicide, distributed approximately in equal shares). In the case of maize, 68.2% of the cumulative benefits went to farmers, 11.4% to the National Government, and 20.4% to technology suppliers (with 19% going to the seed sector). Finally, in the case of cotton, benefits largely went to farmers (96%), with 4% being distributed to technology providers (3% to seed suppliers and the rest to agrochemical suppliers).

Given the importance of Argentine soybeans production worldwide, using the same information as the one generated for the economic impact analysis concerning Argentina, it has been estimated the global impact in terms of savings that the adoption of GM technology by Argentine farmers has had on consumer expenditure (by reducing the global price). The total cumulative figure for the period 1996-2010 was estimated at about US$ 89 billion which, added to the cumulative gross benefits in Argentina (US$ 65 billion), would result in a total herbicide-tolerant soybeans benefits of about US$ 154 billion. In terms of prices, the estimated figures show that if this adoption process had not occurred, the international price of soybeans in 2011 would have been 14% higher than it actually was.

This paper is divided into five chapters. Chapter 1, designed to be an introduction, summarizes the highlights on the process of introduction of genetically modified crops in Argentine agriculture, through the history of approvals for field trials and commercial plantings, the composition (by crop and trait), and their origin, as well as the adoption dynamics compared to other technologies of significance at national and international level.

Chapter 2 represents the core part of this study, which is the analysis of the economic impact of GM technologies introduced in Argentine agriculture. Based on the same methodology, Chapter 3 shows an estimate of the potential future benefits that could be generated from the commercial cultivation of an herbicide-tolerant and insect-resistant soybean (combined traits) and a drought-tolerant wheat, for three possible scenarios relating to prices and GM technology adoption. Results show that, if such technologies were released as from the next crop season, cumulative benefits in the following ten years would amount to US$ 9,131-26,073 million in the case of soybeans, and US$ 526-1,923 million in the case of wheat, depending on the different scenarios.

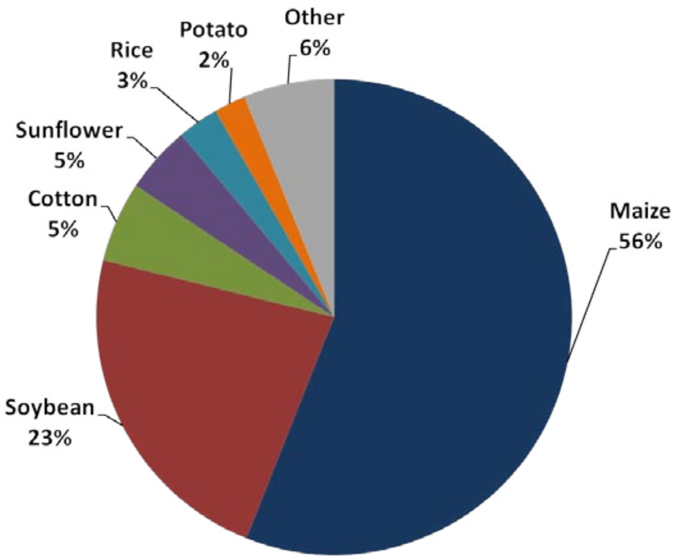
Chapter 4 analyzes some environmental impacts related to the new technologies, with emphasis on the particular existing synergy between the expansion of GM varieties and the practice of no-till farming, as well as the positive impact of the latter on the soil structure and energy efficiency of agricultural practices. These practices have led to a 38% reduction in fuel consumption for such crops, as well as a substantial reduction in the use of residual herbicides, which meant a significant positive impact on the environment. However, these practices have also raised many questions such as, for example, those associated with the expansion of soybeans monoculture and the implication of such circumstance in terms of “export” of soil nutrients, and the expansion of agriculture towards the non-pampean region with more “fragile” resources. All these aspects are very important and they should be monitored, but there is no doubt that the herbicide-tolerant + no-till farming package is a compelling alternative regarding the previous situation, even though it cannot solve by itself all the sustainability problems that are implied in the process of agricultural intensification.

Finally, Chapter 5 offers a perspective on past and future benefits as an overall conclusion to the paper. The emphasis is in the benefits that Argentina has been able to have as an early adopter of the new technologies and the challenge of maintaining such a position. Stemming from the information presented throughout this paper, there is a description of the advantages that Argentina was able to internalize by being at the forefront of such type of innovative processes and, additionally, of the risks –or opportunity costs- that may affect Argentina if a process of technology adoption in the future were less dynamic than it has been in the past. Drifting apart from the innovation frontier may have disturbing consequences for Argentina, perhaps of a much more serious nature in the future than the impact that the country may have suffered in the past. Therefore, preserving the early adopter status may seem to be a strategic matter of discussion, where it should be appropriate to include issues such as developing mechanisms for commercial releases, promoting investments in the agricultural sector, and redistributing benefits in the areas of innovation, economic growth and welfare assistance.

CHAPTER 1
GM CROPS IN ARGENTINE AGRICULTURE

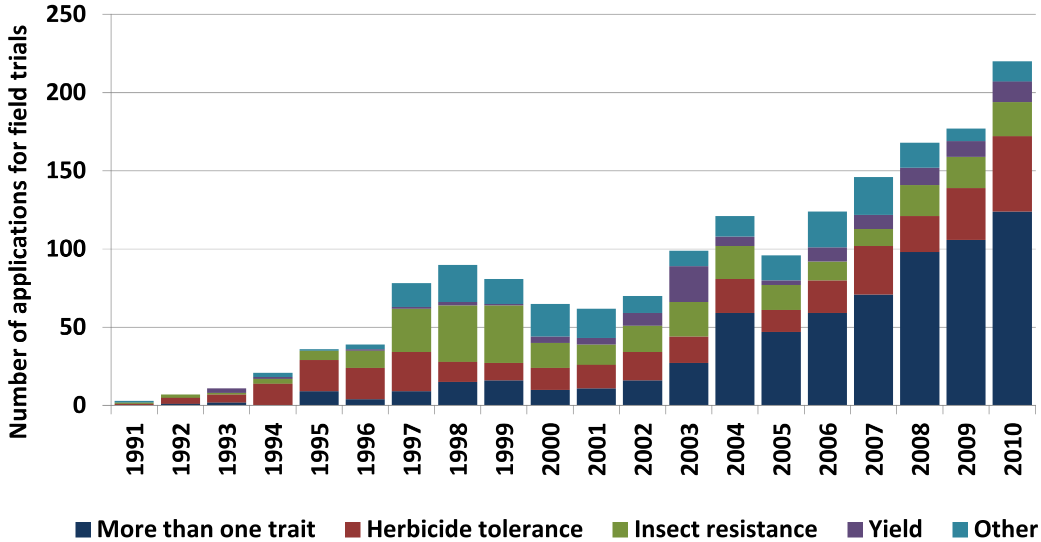
The first genetically-modified (GM) crop introduced in Argentine agriculture was glyphosate herbicide-tolerant soybeans, which was incorporated in the course of the 1996/1997 crop season. However, the process of introducing GM technologies is institutionally rooted in a previous period, precisely in 1991, when Argentina's National Advisory Commission on Agricultural Biotechnology (CONABIA) was created under the scope of the then Secretariat of Agriculture, Livestock, Fisheries and Food (SAGPyA). At that time, CONABIA was responsible for the regulatory process governing the testing and commercial release of GM events, and it largely facilitated that the new technologies be rapidly incorporated into Argentina's productive systems. Ever since its inception, within the CONABIA framework, approval has been granted to 1,721 applications for field trials; maize, soybeans, cotton and sunflower being the crops with the greatest number of executed trials, followed by wheat, rice, potato and forage crops (alfalfa), among others (Figure 1.1). As to the technology traits (Figure 1.2), there has been a significant evolution from single traits (herbicide tolerance, insect resistance) to combined traits, which clearly prevails towards the end of such period, thus showing the trend followed by GM technologies elsewhere around the world (James, 2010). Finally, as to their origin (Figure 1.3), there is a clear dominance of foreign technologies, which account for the bulk of field trials all over the period.

Figure 1.1. Field trials by crop (1991-2010)



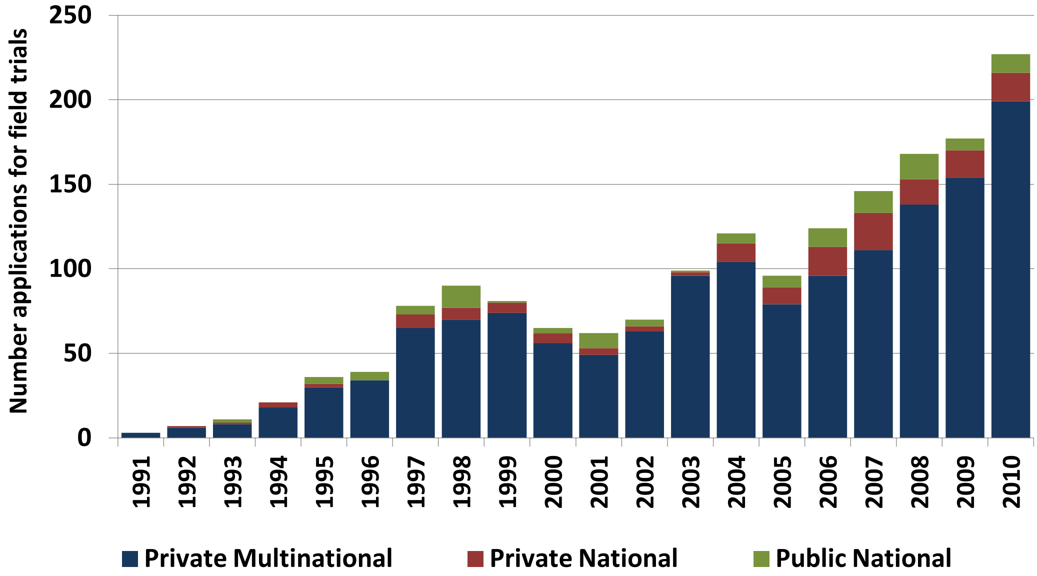
Source: Ministry of Agriculture, Livestock and Fisheries

Figure 1.2. Evolution of the trait type of GM technologies subject to field trials in Argentina (1991-2010)



Source: The authors, based on data from the Ministry of Agriculture, Livestock and Fisheries

Figure 1.3. Origin of field trials authorized in Argentina (1991-2010)



Source: The authors, based on data from the Ministry of Agriculture, Livestock and Fisheries

At commercial level, after the approval of the glyphosate-tolerant soybeans, other twenty events have been approved for planting, food and feed consumption and commercialization, including 15 maize, 3 cotton and 2 soybeans (Table 1.1). These technologies were used in nearly 22.9 million hectares in the last crop season (2010/2011), of which 19 million were grown with herbicide-tolerant soybeans, 3.5 with GM maize (1.6 million insect-resistant, 300 thousand herbicide-tolerant, and 1.6 million having both traits combined); and 614 thousand hectares with GM cotton (56 thousand herbicide-tolerant, 8 thousand insect-resistant, and 550 thousand having both traits combined) (ArgenBio, 2011). These figures approximately represent 100%, 86% and 99%, respectively, of the total area grown with each of these species (Figure 1.4). These numbers put Argentina third, behind the USA and Brazil, as to

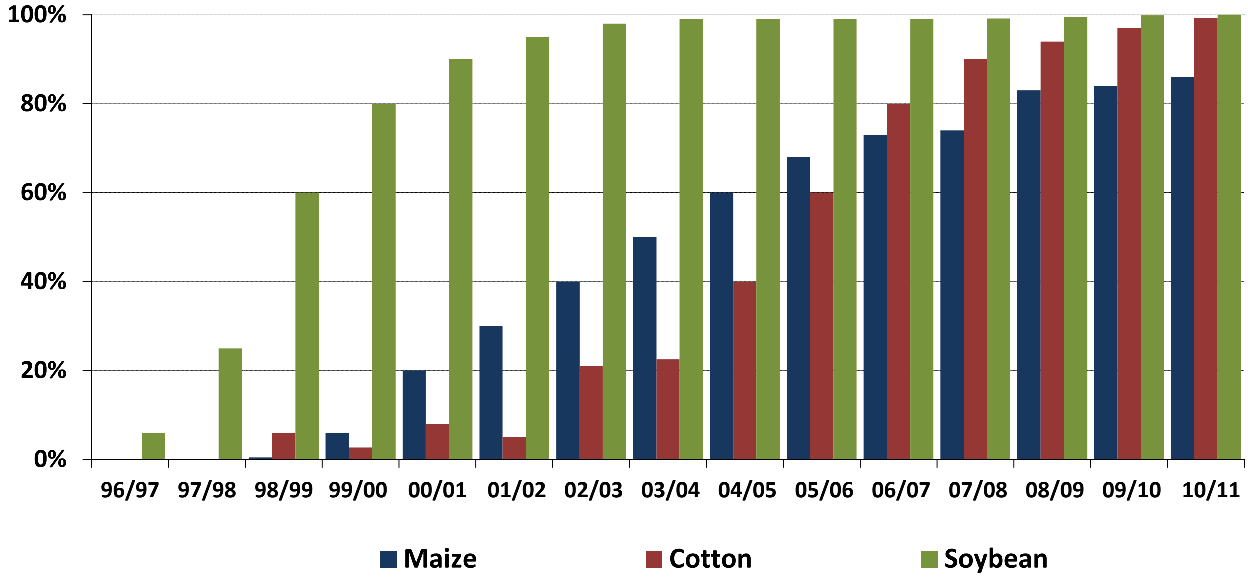
GM crop area at world level; India and Canada being the countries ranked in the immediately following positions (James, 2010).

Table 1.1. GM events authorized for planting, food/feed, and commercialization in Argentina

Crop	Traits	Applicant	Year
Soybeans	Glyphosate tolerance (40-3-2)	Nidera S. A.	1996
	Glufosinate ammonium tolerance (A2704-12)	Bayer S.A.	2011
	Glufosinate ammonium tolerance (A5547-127)	Bayer S.A.	2011
Cotton	Lepidopteran resistance (MON 531)	Monsanto Argentina S.A.I.C.	1998
	Glyphosate tolerance (MON 1445)	Monsanto Argentina S.A.I.C.	2001
	Lepidopteran resistance and glyphosate tolerance (MON 531x MON 445)	Monsanto Argentina S.A.I.C.	2009
Maize	Lepidopteran resistance (176)	Ciba-Geigy S. A.	1998
	Lepidopteran resistance (MON 810)	Monsanto Argentina S.A.I.C.	1998
	Glufosinate ammonium tolerance (T25)	AgrEvo S. A.	1998
	Lepidopteran resistance (Bt11)	Novartis Agrosem S.A.	2001
	Glyphosate tolerance (NK 603)	Monsanto Argentina S.A.I.C.	2004
	Glyphosate tolerance (GA 21)	Syngenta Seeds S.A.	2005
	Lepidopteran resistance and glufosinate ammonium tolerance (TC 1507)	Dow AgroSciences Argentina S.A., Pioneer Argentina S.A	2005
	Lepidopteran resistance and glyphosate tolerance (NK 603 x MON 810)	Monsanto Argentina S.A.I.C.	2007
	Lepidopteran resistance and glufosinate ammonium and glyphosate tolerance (1507 x NK 603)	Dow AgroSciences Argentina S.A., Pioneer Argentina S.R.L.	2008
	Lepidopteran resistance and glyphosate tolerance (Bt11 x GA21)	Syngenta Agro S.A.	2009
	Lepidopteran resistance (MON 89034)	Monsanto Argentina S.A.I.C.	2010
	Glyphosate tolerance and Coleopteran resistance (MON 88017)	Monsanto Argentina S.A.I.C.	2010
	Glyphosate tolerance and Lepidopteran and Coleopteran resistance (MON 89034 x MON 88017)	Monsanto Argentina S.A.I.C.	2010
	Lepidopteran resistance (MIR162)	Syngenta Agro S.A.	2011
	Lepidopteran resistance and glyphosate tolerance (Bt 11 x GA21 x MIR 162)	Syngenta Agro S.A.	2011

Source: Ministry of Agriculture, Livestock and Fisheries

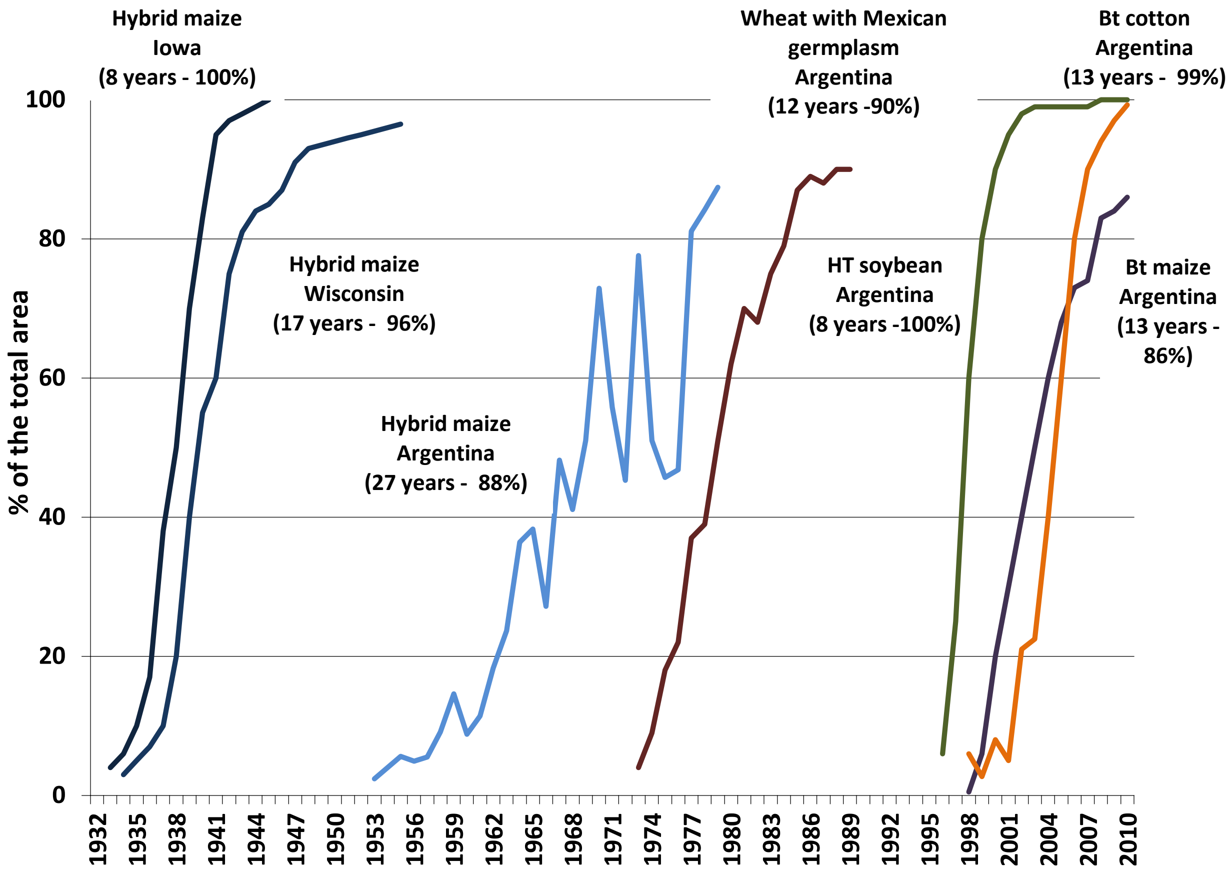
Figure 1.4. Evolution of GM crop share in the total area for each crop



Source: ArgenBio

This adoption dynamics represents an almost unprecedented process at world level, only comparable to what happened with hybrid maize in the State of Iowa (USA) in the 1930s, but much more expedite than what it occurred with GM technologies in other American Corn Belt States and, later on, in other parts of the world with the so-called "Green Revolution" technologies. Even within the Argentine experience, the evolution of the adoption of GM technologies into productive processes compares very positively against other previous cases, such as hybrid maize and wheat with Mexican germplasm (Figure 1.5). It took hybrid maize 27 years to reach the percentage of acceptance now enjoyed by GM maize after only 13 years, and it took Mexican wheat 12 years to be as widely adopted as soybeans in only 4 crop seasons (90% market share).

Figure 1.5. Rate of adoption for different GM technologies in Argentina and the US

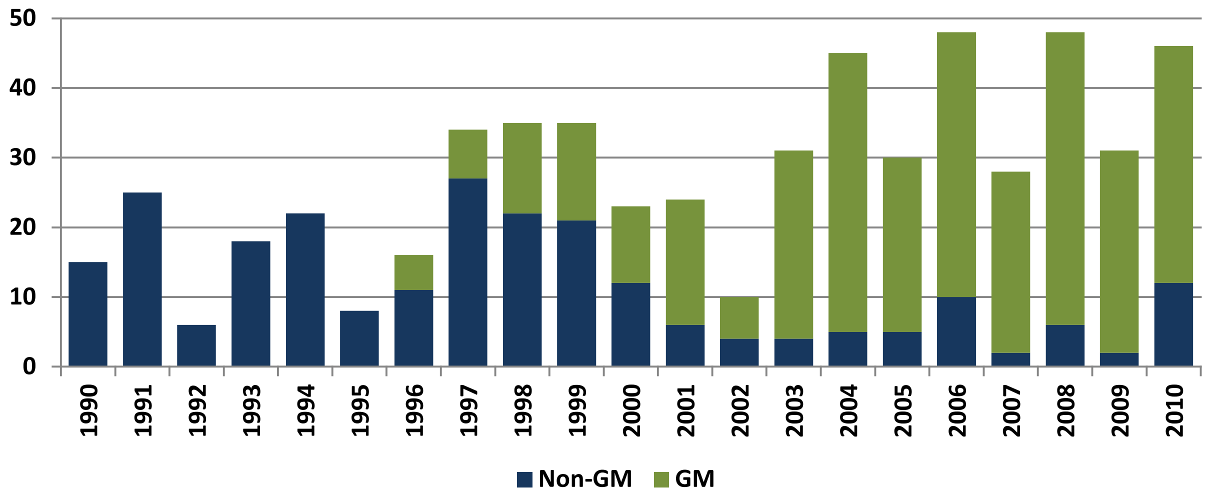


Source: The authors, based on Trigo and Cap 2006, and ArgenBio 2011

Besides the institutional framework, which, as mentioned, was key for the development of GM technologies to evolve successfully, other aspects that also had an impact on the adoption process were the similarity of the agro-ecological conditions for which such technologies had been developed originally and, upon the emergence of such innovations, the existence of a consolidated technology services infrastructure, particularly regarding the seed industry (Trigo et al., 2002; Trigo and Cap, 2006). The similarity of agro-ecological conditions facilitated the transfer of new concepts, in a clear process of taking advantage of technology "spillovers", and the seed industry played a key role in the subsequent and quick spread of the new technologies, once they were available on the domestic scenario. In this regard, the commercial success of GM varieties is very much associated with the possibility of incorporating the new genes into a genetic background that is well adapted agronomically to local conditions, and the existence of a seed industry able to deliver the new varieties to farmers quickly and effectively. In the case of Argentina, both conditions were met (Trigo et al., 2002).

By the time the first glyphosate-tolerant soybeans came along, there had been a significant plant breeding activity in Argentina, both in the public and private sectors, with a total of 203 registered soybean varieties, about 10% originating in the public sector (mainly INTA) and the remainder in the private sector which allowed the new genes to be rapidly incorporated into the productive cycle. From 1996 onwards, there has been a quantitative leap forward in the number of registered varieties (Figure 1.6), most of them being GM varieties.

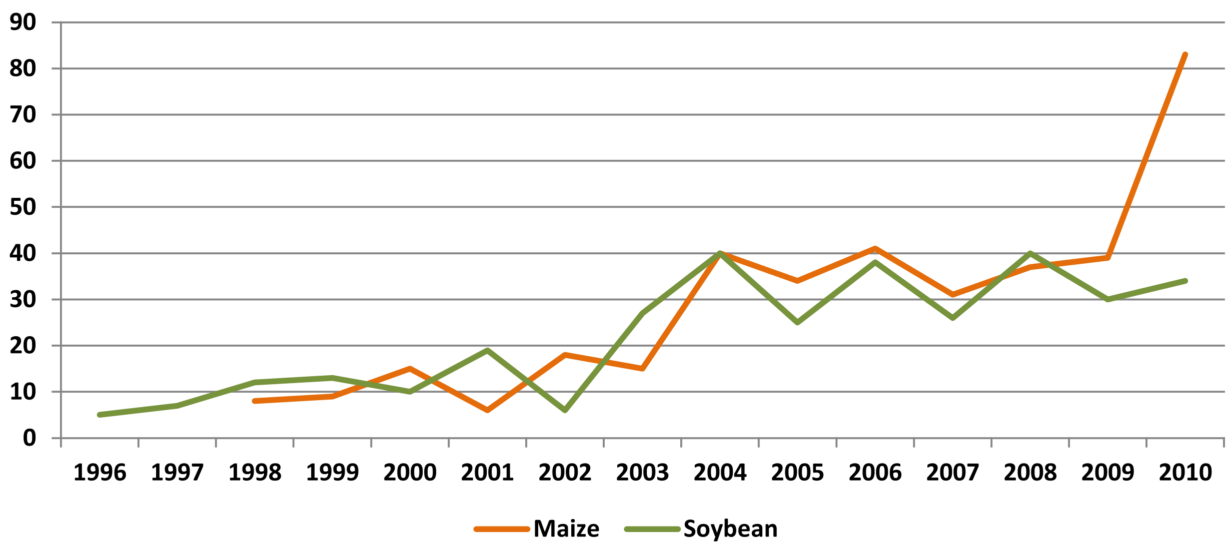
Figure 1.6. Evolution of GM and non-GM soybean varieties in Argentina's National Registry of Cultivars (as a % of the total amount)



Source: INASE

In the case of maize, the registration process has been similar to the one required for soybean varieties. As from 1998, GM hybrids started to be registered and, since then, they became the rule, not the exception, in the Registry of Cultivars (Figure 1.7).

Figure 1.7. Evolution of GM soybean varieties and GM maize hybrids in Argentina's National Registry of Cultivars (as a % of the total amount)



Source: INASE

Finally, the dynamism of the adoption process also reflects the synergy between herbicide-tolerant soybeans and no-till farming (NTF) [1] practices and, further along the cycle, the significant drop in the price of glyphosate as a result of the expiration of the patent and the rapid expansion of the supply sources following such circumstance. Regardless of these technical and economic aspects, it should also be underscored the role played in this process by the organizational changes occurring in the agriculture of the Pampas region from the mid-1980s onwards. In this regard, the widespread use of the so-called “network agricultural” practices rendered several aspects flexible, such as access to resources (land, knowledge and capital), and also facilitated a professional management of the agricultural operation and, through such mechanisms, these practices became a major driver for the adoption of new technologies (Trigo et al., 2010). This aspect, as well as the environmental impact implications of the existing synergy among these technologies, will be addressed further on in Chapter 4 of this document.

[1] No-till farming (NTF) basically consists in placing the seed in the soil at the required depth with minimal disturbance to the soil structure. This is performed by using machinery specifically designed for such purpose, which eliminates the need for plowing and minimizes tillage practices required for implanting the crop.

CHAPTER 2

ECONOMIC IMPACTS OF GM CROPS IN ARGENTINE AGRICULTURE

2.1 Introduction and methodological approach

The analytical tool used to estimate the economic impacts of GM events availability in Argentina's agricultural sector is a dynamic simulation model (SIGMA), developed by INTA (National Institute of Agricultural Technology). The model replicates, through simulations, the situations that occur in the field in countries like Argentina, that show a great diversity of technological and productive realities, that cannot be attributed to agro-ecological differences but to socio-economic factors.

The key component of the model is the replication of the farmer's adoption process of technological innovations that introduce changes in the production function, inducing a more efficient use of resources, which in turn leads to an increase in crop yields and/or to a reduction in unit costs and/or to an improvement in the quality of the product and/or to an expansion of the area potentially suitable for its commercial production.

The model may be used for *ex-ante* and *ex-post* studies, and the final result is an estimate of the effects of alternative technology generation and adoption scenarios (regional or national) on aggregate production. This means that SIGMA calculates social benefits (rather than private benefits). That is to say, how much more it could be produced (in volume and value) compared with a defined baseline owing to the adoption (through pathways that vary according to farmer's profile) of technologies already available on the market or to be generated in the future by the R&D system (for further details, see Appendix I).

The data (unbundled at the level of homogeneous agro-ecological zone) used in the simulation runs included in this Chapter were obtained from the Technological Profile Study of the Argentine Agricultural Sector (INTA, 2002), supplemented by information taken from the Ministry of Agriculture, Livestock and Fisheries of Argentina (MAGyP), ArgenBio, the National Institute for Statistics and Censuses (INDEC), and the United Nations Food and Agriculture Organization (FAO).

2.2 GM soybeans: A retrospective analysis of its adoption impacts (1996-2010)

2.2.1 Direct economic impacts at the national level

2.2.1.1 Benefits from the reduction of production costs

It was assumed (on a conservative basis because we preferred to underestimate it) that the adoption of GM varieties containing the glyphosate tolerance gene implies an average cost reduction amounting to USD 20/ha (Penna and Lema, 2003). This reduction is applicable to both first-crop and second-crop soybeans (following wheat), and it mainly originates in the elimination of tilling practices and inputs associated with the use of pre- and post-emergence selective herbicides, which are indeed required by conventional varieties. These benefits are applicable to the whole area planted with soybeans every year, always adjusting for the adoption percentage relevant to each particular year. Table 2.1 presents a summary of aggregate values at national level.

Table 2.1. Evolution of gross benefits from the adoption of GM soybeans due to the reduction of production costs

SEASON	AREA WITH GM SOYBEANS	GROSS BENEFITS
	(HA)	(M USD)*
1996/97	370,000	7.40
1997/98	1.800,000	36.00
1998/99	4.875,396	97.51
1999/00	6,870,511	137.41
2000/01	8,783,542	175.67
2001/02	10,381,943	207.64
2002/03	11,756,084	235.12
2003/04	13,057,989	261.16
2004/05	14,407,585	288.15
2005/06	15,859,058	317.18
2006/07	16,141,337	322.83
2007/08	16,603,525	332.07
2008/09	18,032,805	360.66
2009/10	18,343,272	366.87
2010/11	18,650,000	373.00
TOTAL 1996-2010		**3,518.66**

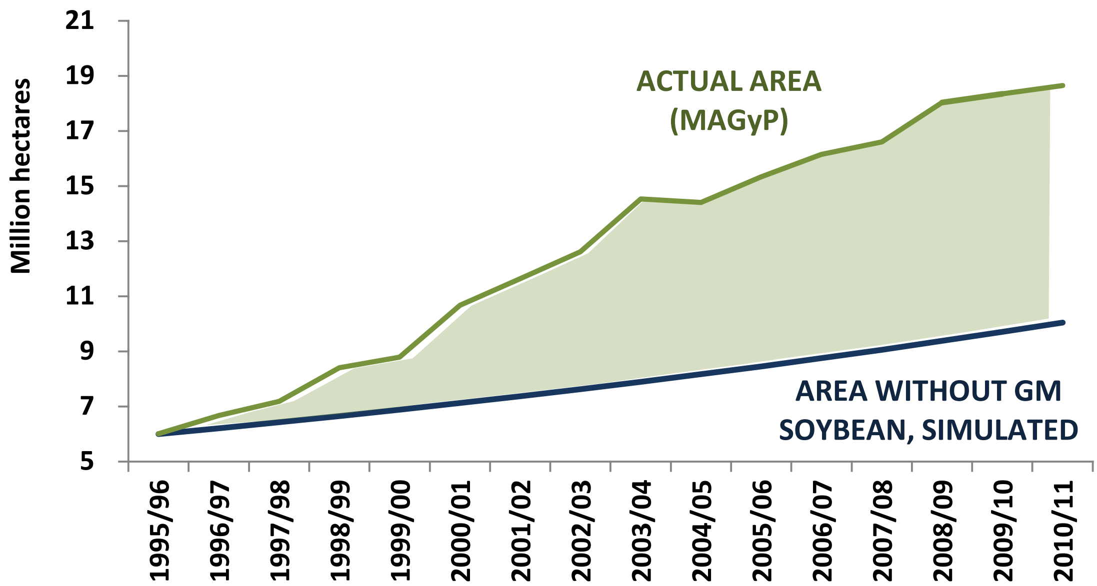
*M: million

Source: The authors, based on estimates from ArgenBio, data from the Ministry of Agriculture, Livestock and Fisheries (MAGyP), and SIGMA v2.0 simulation runs (2011).

2.2.1.2 Benefits from the expansion of planted area

After the approval of the herbicide-tolerant event in 1996, there was a dramatic upward change in the expansion of the area planted with soybeans. For the period 1971-1996, the area's annual increase rate was 3.5%. However, for the period 1996-2010, the rate went up to 9.4%. In order to estimate the magnitude and evolution of the gross benefits flow resulting from the adoption of GM soybeans, we have applied a counterfactual approach, contrasting the time-series of the area actually planted with this oilseed, as published by SAGPyA (Secretariat for Agriculture, Livestock, Fisheries and Food), and since 2007 by MAGyP (Ministry of Agriculture, Livestock and Fisheries), with the results of a SIGMA simulation run, with an annual expansion rate of 3.5% for the whole period (reconstructing a sequence of events that did not occur, due to the availability of GM materials) (Figure 2.1).

Figure 2.1. Evolution of the actual planted area vs. planted area without the release of GM soybeans, simulated by SIGMA



Source: The authors, based on MAGyP data and SIGMA V2.2 runs (2011)

Table 2.2 shows the evolution of the increase in the area planted with soybeans in the period 1996-2010, attributable to the adoption of GM materials.

Table 2.2. Actual area planted with soybeans since the introduction of GM varieties (MAGyP data) and simulated planted area without GM soybeans (SIGMA)

SEASON	PLANTED AREA (HA)		GM DIFFERENCE
	MAGYP	SIMULATED WITHOUT GM SOYBEANS	
1996/1997	6,669,500	6,291,689	377,811
1997/1998	7,176,250	6,369,623	806,627
1998/1999	8,400,000	7,107,989	1,292,011
1999/2000	8,790,500	6,950,402	1,840,098
2000/2001	10,664,330	8,206,674	2,457,656
2001/2002	11,639,240	8,487,098	3,152,142
2002/2003	12,606,845	8,675,062	3,931,783
2003/2004	14,526,606	9,720,962	4,805,644
2004/2005	14,399,998	8,616,285	5,783,713
2005/2006	15,329,000	8,451,997	6,877,003
2006/2007	16,141,337	8,749,387	7,391,950
2007/2008	16,603,525	9,055,615	7,547,910
2008/2009	18,032,805	9,372,562	8,660,243
2009/2010	18,343,272	9,700,602	8,642,670
2010/2011	18,650,000	10,040,123	8,609,877

Source: The authors, based on MAGyP data and SIGMA V2.2 runs (2011).

Table 2.3 shows the evolution of gross benefits (measured in US dollars) which was estimated by making, based on average Buenos Aires FOB prices for the period 1996-2010, a valuation of the production obtained in each crop season that is attributable to the expansion of the area planted with soybeans as a result of the adoption of GM materials.

Table 2.3. Evolution of gross benefits from the introduction of GM soybeans due to the expansion of the planted area

SEASON	PLANTED AREA GM DIFFERENCE (HA)	YIELD (T/HA)	FOB PRICE (USD/T)	GROSS BENEFITS (M USD)
1996/97	377,811	1.72	296.50	192.81
1997/98	806,627	2.69	221.83	481.99
1998/99	1,292,011	2.45	175.33	553.86
1999/00	1,840,098	2.33	187.42	803.96
2000/01	2,457,656	2.58	171.50	1,089.38
2001/02	3,152,142	2.63	198.00	1,641.70
2002/03	3,931,783	2.80	238.42	2,627.95
2003/04	4,805,644	2.21	268.08	2,843.92
2004/05	5,783,713	2.73	230.67	3,640.17
2005/06	6,877,003	2.64	225.56	4,098.36
2006/07	7,391,950	2.97	270.33	5,936.92
2007/08	7,547,910	2.82	486.00	10,348.23
2008/09	8,660,243	1.85	424.67	6,796.42
2009/10	8,642,670	2.91	362.67	9,105.46
2010/11	8,609,877	2.70	505.33	11,756.02
Total 1996-2010				**61,917.15**

Source: The authors, based on MAGyP data and results from SIGMA simulation runs (2011).

Table 2.4 shows the evolution, for the period 1996-2010, of gross benefits due to cost reduction and the expansion of planted area, as well as total gross benefits.

Table 2.4. Evolution of total gross benefits from GM soybeans release

SEASON	GROSS BENEFITS DUE TO COST REDUCTION (M USD)	GROSS BENEFIT DUE TO EXPANSION OF CULTIVABLE AREA (M USD)	TOTAL GROSS BENEFITS (M USD)
1996/97	7.40	192.81	200.21
1997/98	36.00	481.99	517.9
1998/99	97.51	553.86	651.37
1999/00	137.41	803.96	941.37
2000/01	175.67	1,089.38	1,265.05
2001/02	207.64	1,641,70	1,849.33
2002/03	235.12	2,627.95	2,863.07
2003/04	261.16	2,843.92	3,105.08
2004/05	288.15	3,640.17	3,928.32
2005/06	317.18	4,098.36	4,415.55
2006/07	322.83	5,936.92	6,259.75
2007/08	332.07	10,348.23	10,680.30
2008/09	360.66	6,796.42	7,157.08
2009/10	366.87	9,105.46	9,472.32
2010/11	373.00	11,756.02	12,129.02
Total 1996-2010	**3,518.66**	**61,917.15**	**65,435.81**

Source: The authors, based on data from SIGMA v2.0 simulation runs (2011).

Table 2.5 shows the distribution of the total gross benefits flow for the period 1996-2010, among the main sector players: farmers, suppliers of GM technology-related inputs, and the National Government (revenues from export duties, in full force since the 2002/2003 crop season).

Table 2.5. Distribution of benefits from GM soybeans

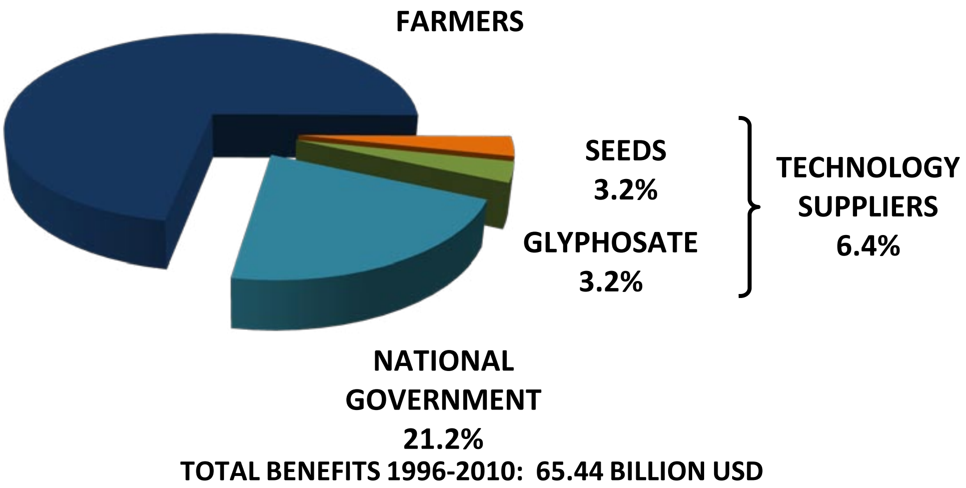
SEASON	TOTAL GROSS BENEFITS (M USD)	AREA WITH GM (ha)	FARMERS (M USD)	TECHNOLOGY SUPPLIERS (M USD)		NATIONAL GOVERNMENT (M USD)
				SEEDS (*)	GLYPHOSATE	
1996/97	200	370,000	189	6	5	-
1997/98	518	1,800,000	467	27	23	-
1998/99	651	4,875,396	526	74	51	-
1999/00	941	6,870,511	722	110	109	-
2000/01	1,265	8,783,542	1,062	72	131	-
2001/02	1,849	10,381,943	1,641	83	125	-
2002/03	2,863	11,756,084	2,132	83	122	526
2003/04	3,105	13,057,989	2,322	94	120	569
2004/05	3,928	14,407,585	2,928	88	184	728
2005/06	4,416	15,859,058	3,296	134	165	820
2006/07	6,260	16,141,337	4,920	234	213	893
2007/08	10,680	16,603,525	8,436	226	287	1,731
2008/09	7,157	18,032,805	3,784	202	240	2,931
2009/10	9,472	18,343,272	6,559	356	190	2,367
2010/11	12,129	18,650,000	8,383	281	154	3,311
Total	**65,436**		**47,369**	**2,070**	**2,121**	**13,876**
				4,191		
PERCENTAGE			**72.4%**	**3.2%**	**3.2%**	**21.2%**

(*) For the first ten crop seasons, the computed amount was equal to 20% of the area grown with GM soybeans (the remaining 80% is distributed as follows: proprietary use, 32%, and illegal seed, 48%). However, for the last five crop seasons, the computed amount was equal to 50% of the area grown with GM soybeans (the remaining 50% corresponding to proprietary seed use and illegal seed).

Source: The authors, based on data from Márgenes Agropecuarios, Costamagna, O. (2004), National Institute for Statistics and Censuses (INDEC), and SIGMA v2.0 simulation runs (2011).

Figure 2.2 summarizes the distribution of cumulative gross benefits for the period 1996-2010, among different players.

Figure 2.2. Distribution of cumulative benefits generated by GM soybeans during the 1996-2010 period.



Source: Table 2.5

2.2.2 Impacts at the global level

World soybeans production in 1996 amounted to 130.2 million tons. Cumulative annual increase for the period 1996-2010 was 959.1 million tons. Considering that the cumulative soybeans production increase in Argentina attributable to the availability of GM technology was 216.1 million tons (Table 2.6), the adoption of this technology in our country would account for 22.53% of the total amount resulting from world soybeans expansion. But, what is the impact of this increased volume of soybeans supply on the international price of such oilseed?

The global impact of the adoption of GM soybeans materials in Argentina has been very significant. Table 2.6 shows the evolution of the contribution to the increase in domestic soybeans production on the world output attributable to the GM technology package, and estimates the price effect on the actually observed values. This means that a counterfactual comparison was made between vectors such as the average FOB prices at Argentine Ports recorded for the period under study (1996-2010) and the estimates obtained according to the procedure described in Appendix II. Strictly expressed in terms of savings in consumer expenditure, the total cumulative figure for the period 1996-2010 reaches USD 89 billion. This figure should be added to the gross benefits in Argentina estimated in a preceding section (USD 65.44 billion)[2], thus reaching an aggregate amount, for the total impact of GM soybeans technology since its availability in our country, of USD 154.43 billion.

[2] According to Trigo and Cap (2006), the increased productivity of sectors that reduced their planted area due to the expansion of soybeans has exceedingly offset the area reduction and, therefore, gross benefits can approximately be equal to net benefits.

Table 2.6. Soybeans: Evolution of world production, contribution of Argentina due to GM materials, impact on world prices, and reduction in consumer expenditure at global level

SEASON	WORLD PRODUCTION (TONS)	Δ PRODUCTION DUE TO GM IN ARGENTINA (TONS)	FOB PRICE (USD/T)	IMPACT ON SOYBEANS PRICE (%)	Δ CONSUMER EXPENDITURE (M USD)
1996/97	130,209,870	774,870	296.50	-0.74	-280.24
1997/98	144,412,830	2,512,725	221.83	-2.17	-970.54
1998/99	160,098,390	3,842,527	175.33	-3.00	-1,088.72
1999/00	157,800,470	4,935,955	187,42	-3.91	-1,028.32
2000/01	161,405,690	7,897,136	171,50	-6.12	-1,895.31
2001/02	177,935,970	10157,698	198.00	-7.14	-2,014,61
2002/03	181,735,440	13,230,491	238.42	-9.10	-2,927,25
2003/04	190,595,630	13,209,410	268.08	-8.66	-3,649,10
2004/05	206,461,490	17,385,401	230.67	-10.53	-6,454,33
2005/06	214,347,289	19,725,414	225.56	-11.39	-5,656,36
2006/07	236,233,000	22,987,589	270.33	-12.16	-7,767.89
2007/08	220,406,000	23,688,477	486.00	-13.43	-14,390.75
2008/09	211,964,000	16,699,679	424.67	-9.85	-8,864.75
2009/10	260,270,000	29,696,480	362.67	-14.26	-13,462.40
2010/11	258,402,000	29,361,930	505.33	-14.20	-18,546.95
Total 1996-2010	**2,912,278,069**	**216,105,782**			**-88,997.52**

Source: The authors, based on data from USDA Official Estimates, MAGyP, and SIGMA v.2.0 simulation runs (2011)

2.3 GM maize. A retrospective analysis of its adoption impacts (1998-2010)[3]

2.3.1 Benefits from lepidopteran-resistant (Bt) maize

Trigo and Cap (2006) describe the methodological approach and specify in detail the assumptions used to estimate the benefits of adopting Bt technology for maize. In particular, the authors consider that the benefit of adopting Bt technology consists in preventing yield losses caused by the attack of certain pests, mainly *Diatraea saccharalis* and *Spodoptera frugiperda*, in their larval state. This means that the net final result of the crop-pest-Bt germplasm interaction is a stochastic variable and, therefore, modeling its impact is more complex than in a deterministic case, like improvements in productivity indicators, reduction in costs or increase in crop yield, where the random component is associated almost exclusively with "climate risk", that is to say, with temperatures on the one hand, as well as time of year and volume of rainfall on the other.

Ianonne (2002) estimated that, for the "maize-belt" region, the level of damage ranges between 10 and 50%, depending on the severity of the attack and the time of sowing (the later the sowing, the more severe the damage; double-cropping maize being the hardest hit). In his paper, the authors estimated total annual losses for the Pampas region at USD 170 million.

2.3.2 Benefits from lepidopteran-resistant and herbicide-tolerant (Bt+HT) maize

In the case of materials with stacked Bt+HT events, in addition to the Bt maize effects described in the foregoing section, there is a cost reduction of 20 USD/ha.

2.3.3 Summary of impacts from Bt and Bt+HT maize

Maize with combined Bt+HT events represents an improvement compared to those which only contain single Bt events and, therefore, starting from the 2007/2008 crop season, there has been a gradual replacement of Bt with Bt+HT maize, maintaining the desirable features of the single Bt event. Considering the limitations of the SIGMA simulation model, in the sense of assuming that the adoption of a technology that improves on the pre-existing state of the art is irreversible, it was necessary to introduce an adjustment coefficient on the Bt estimated area for the 2007/2008 – 2010/2011 seasons, in order not to overestimate the impact of the availability of both technologies, and make the results from simulation runs on the area planted with each one of the two technology consistent with those reported by ArgenBio.

Table 2.7 shows the evolution of gross benefits generated by the adoption of Bt and Bt+HT technologies, as well as their distribution among the main sector players: farmers, suppliers of GM technology-related inputs, and the National Government (revenues from export duties) (also see Figure 2.3).

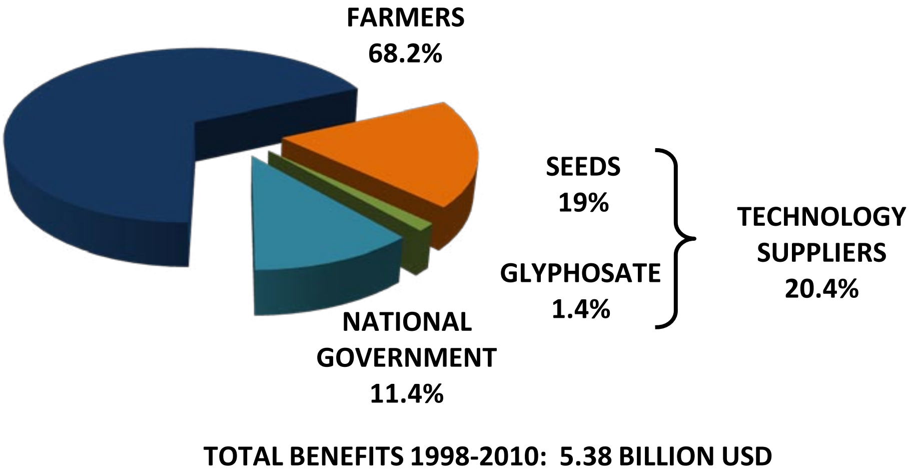
[3] This paper examines Bt and Bt+HT maize only, since the adoption of maize with single HT events has been little significant, and its usefulness has rapidly been superseded by maize hybrids with combined Bt+HT events.

Table 2.7. Evolution and distribution of benefits from the adoption of Bt and Bt+HT maize

SEASON	TOTAL GROSS BENEFITS	AREA WITH Bt AND Bt+HT	NET BENEFIT (M USD)			
			FARMERS	TECHNOLOGY PROVIDERS		NATIONAL GOVERNMENT
	(M USD)	(HA)		SEEDS (*)	GLYPHOSATE	
1998/99	8	113,738	5.3	2.3	-	0,0
1999/00	17	270,884	11.2	5.4	-	0,0
2000/01	32	557,665	20.6	11.2	-	0,0
2001/02	48	944,280	43.7	4.7	-	0,0
2002/03	72	1,315,787	33.9	23.7	-	14.4
2003/04	95	1,574,408	36.3	39.4	-	18.9
2004/05	119	1,713,267	36.8	58.3	-	23.8
2005/06	92	1,777,478	20.4	53.3	-	18.4
2006/07	595	2,409,521	402.8	94.0	-	98.1
2007/08	1,131	3,169,328	787.4	180.7	14.2	148.9
2008/09	673	2,621,191	365.6	196.6	28.2	82.9
2009/10	788	2,975,404	479.2	169.6	17.1	122.2
2010/11	1,706	3,176,327	1,422.0	181.1	16.5	86.7
Total	**5,375**		**3,665**	**1,020**	**76**	**614**
PERCENTAGE			**68.2%**	**19%**	**1.4%**	**11.4%**

(*) The benefit to seed suppliers was computed on the basis of the price differential between the GM seed price and the conventional hybrid maize price, that is to say, the additional direct cost per hectare associated with the adoption of the new technology available. Source: The authors, based on data from Márgenes Agropecuarios, MAGyP, Comtrade and SIGMA v2.2 simulation runs (2011)

Figure 2.3. Distribution of cumulative benefits resulting from the adoption of Bt and Bt+HT maize



Source: Table 2.7

2.4 GM cotton. A retrospective analysis of its adoption impacts (1998-2010)

Due to the limitations of the SIGMA model to reproduce non-trend related changes in the area devoted to a specific activity, as it has been the case of cotton for the last 13 years (as a result of price volatility, fierce GM soybeans competition, the occurrence of flooding, etc.), the analysis was tackled by making an assumption which is a major simplification of the real world situation: the area grown with cotton remained at 400 thousand hectares throughout the period under study. Anyway, it is understood that even with such restriction, the simulation of the adoption paths of both, Bt and HT, technologies is a good approximation to the observed reality and, if there are errors (as it may probably be the case), the conservative nature of the parameters entered in the model guarantees that the end result would be an underestimation rather than overestimation of the magnitude of the impacts.

On the other hand, the short period of time elapsed between the availability of materials with combined (Bt+HT) events as from the 2008/2009 crop season, made it unadvisable to perform an *ex-post* analysis of the impact caused by its adoption which, as it happens with maize, is characterized by a very quick replacement of single events with combined ones. Therefore, it was decided not to consider the availability of varieties with combined Bt+HT events and to simulate the continuity of the paths of adoption of single events. Finally, their impacts were added up, in the understanding that the values estimated in this way are not significantly different from the ones generated by the adoption of materials with combined events.

2.4.1 Benefits of lepidopteran-resistant (Bt) cotton

The analysis was based on the assumption that the adoption of Bt cotton varieties increases yield by 30%, in line with estimates by Elena (2001).

2.4.2 Benefits of herbicide-tolerant (HT) cotton

The analysis was based on the assumption that the adoption of HT materials reduces production cost by 30 USD/ha, as a result of herbicide savings, net of the seed price differential.

2.4.3 Summary of impacts from Bt and HT cotton

Table 2.8 shows consolidated figures on the evolution of the area planted with GM cotton, as well as the resulting benefits attributable to the adoption of GM technologies for the period under study (1998-2010 for Bt, 2002-2010 for HT, and 2008-2010 for Bt+HT, which almost completely replaced the previous technologies), and the distribution of benefits between farmers and technology providers.

Table 2.8. Evolution and distribution of benefits from Bt and HT cotton

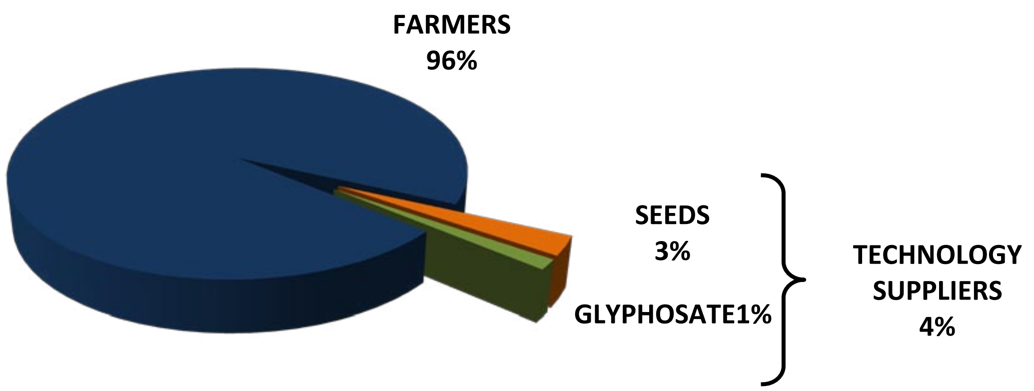
SEASON	GROSS BENEFITS (M USD)	AREA WITH Bt AND HT COTTON (ha)	NET BENEFIT (M USD)		
			FARMERS	TECHNOLOGY PROVIDERS	
				SEEDS (*)	GLYPHOSATE
1998/99	0.09	271	0.08	0.01	-
1999/00	0.34	745	0.33	0.01	-
2000/01	0.81	2,033	0.77	0.04	-
2001/02	1.69	5,449	1.58	0.11	-
2002/03	6.62	14,097	6.34	0.28	-
2003/04	17.09	71,163	15.05	1.34	0.70
2004/05	30.19	147,811	24.93	2.78	2.48
2005/06	63.60	252,835	53.72	4.75	5.12
2006/07	119.06	354,975	109.80	6.67	2.59
2007/08	202.72	426,440	190.36	8.01	4.35
2008/09	206.86	464,948	192.18	8.74	5.94
2009/10	425.06	482,909	413.09	9.07	2.90
2010/11	760.19	491,271	748.44	9.23	2.53
Total	**1,834.32**		**1,756.66**	**51.05**	**26.62**
PERCENTAGE			**96%**	**3%**	**1%**

(*) For the purposes of calculating the benefits to seed suppliers, 34% of the certified seed value was computed in order to capture the "brown bag" (illegal seed) effect (estimated to cover 66% of the planted area). The seed costs for Bt and HT cotton were assumed to be 59.02 and 52.00 USD/ha, respectively, and they were estimated as price differentials between the conventional seed (15.95 USD/ha), and that of the Bt seed (74.98 USD/ha) and the HT seed (67.95 USD/ha).

Source: The authors, based on results from SIGMA simulation runs, data from the Economic and Social Council of Chaco Province, Central Bank of Argentina, and Cueto Rúa, P. (2006), personal communication.

Figure 2.4 shows the distribution of gross benefits generated by the adoption of GM technologies for cotton, between farmers and suppliers of inputs associated with GM technologies (seed and herbicide), cumulative in the 1998-2010 period for Bt cotton, and in 2002-2010 for HT cotton. The National Government has not been included as a beneficiary because, as there are no direct benefits due to the increase in production volume attributable to GM materials, there were no increases in fiscal revenues (even though one may argue that cost reduction could marginally expand the planted area, but the magnitude of the impact would be very small).

Figure 2.4. Distribution of cumulative benefits resulting from the adoption of Bt and HT cotton



Total benefits 1998-2010: 1.83 BILLION USD

Source: Table 2.8

2.5 Summary of economic benefits and job creation generated by GM crops (1996-2010)

2.5.1 Summary of economic benefits from GM crops

Table 2.9 summarizes the economic benefits derived from the adoption of GM crops in Argentina in the 1996/1997-2010/2011 period.

Table 2.9. Summary of the impacts of GM crop adoption in Argentine agriculture in the 1996/1997-2010/2011 period

IMPACT AT THE NATIONAL LEVEL	MILLION USD
GM SOYBEAN	65,435.81
GM MAIZE	5,375.38
GM COTTON	1,834.32
TOTAL NATIONAL LEVEL	**72,645.52**
IMPACT AT THE GLOBAL LEVEL	
SAVINGS IN CONSUMER EXPENDITURES	88,997.52
TOTAL	**161,643.04**

Source: Tables 2.4, 2.6, 2.7 and 2.8

2.5.2 Indirect economic impact at the national level: Job creation

This section updates the estimates performed in a previous paper (Trigo and Cap, 2006) but making a methodological change in the approach which does not modify the assumptions. The most significant assumption refers to the fact that, for each additional dollar in goods generated by the adoption of GM materials (valued at boder price, that is to say, FOB price at Argentine Ports), another dollar is generated in the services sector (transportation, storage, etc).

The calculation procedure, the results of which are summarized in Table 2.10, was the following: stemming from GDP values at market prices (INDEC, 2011), for each year of the period under study (1996-2010), the actual "cost" of adding one job to the economy was estimated in terms of GDP, assuming a baseline stock of 10 million jobs in 1996 with an annual cumulative increase of 330 thousand, but subtracting 500 thousand and 1 million jobs in 2001 and 2002, respectively, in order to account for the impact of the crisis prior and subsequent to the collapse of the fixed peso-dollar exchange rate (pegged at a value of one). Such value, denominated in pesos, was converted into dollars (1 to 1 since 1996 until 2001 inclusive and, from 2002 onwards, based on the annual average of the dollar/peso exchange rate published by the Central Bank of Argentina (BCRA). Finally, it was taken the gross value of additional production estimated for each year as a result of the adoption of GM materials (see Tables 2.4, 2.7 and 2.8), was multiplied by two and divided by the estimated "cost" of one job for each year. The result was considered an approximation to the contribution of GM technologies to the creation of jobs throughout the 15 years under study. The resulting total cumulative figure amounts to 1,817,331 jobs. Should this calculation be correct and accepting the validity of the simplifying assumptions made, during the most critical years (2001 and 2002), the adoption of this technology contributed to the alleviation of unemployment (58 thousand jobs created in 2001, and 253 thousand in 2002). Likewise, the consequences of the sharp decline in production volume in 2008, as a result of drought, translated into a significant loss of jobs (371 thousand), even though the net result had been positive that year due to the performance of other sectors in the economy. It is likely that the construction sector has had the highest exposure to both positive impacts in 2001 and 2002, as well as negative ones in 2008.

Table 2.10. Correlation between GDP growth, benefits from GM materials, and job creation

YEAR	GDP AT MARKET PRICES* (M $)	TOTAL BENEFITS GM CROPS (M USD)	DOLLAR EXCHANGE RATE** ($/USD)	$/JOB	USD/JOB	JOBS CREATED BY THE ADOPTION OF GM CROPS
1996	272,150	200.21	1.00	26,345.57	26,345.57	15,199
1997	292,859	517.99	1.00	26,647.76	26,647.76	23,851
1998	298,948	659.04	1.00	25,660.80	25,660.80	10,993
1999	283,523	958.34	1.00	23,031.93	23,031.93	25,991
2000	284,204	1,297.58	1.00	21,912.39	21,912.39	30,963
2001	268,697	1,899.44	1.00	20,464.33	20.464.33	58,820
2002	312,580	2,941.60	3.09	25,433.70	8,226.53	253,367
2003	375,909	3,216.77	2.94	31,456.85	10,694.46	51,459
2004	447,643	4,077.27	2.94	35,499.08	12,071.78	142,565
2005	531,939	4,571.29	2,92	40,085.81	13,718.62	72,021
2006	654,439	6,973.68	3,07	46,980.54	15,284.85	314,350
2007	812,456	12,014.15	3,11	55,685.80	17.888.15	563,554
2008	1,032,758	8,037.29	3,16	67,721.85	21,437.75	-371,014
2009	1,145,458	10,685.47	3,73	71,996.12	19,320.90	274,126
2010	1,442,655	14,595.40	3.91	87,064.30	22,273.25	351,087
TOTAL NEW JOBS (1996-2010)						**1,817,331**

*INDEC

**BCRA

Source: The authors, based on data from INDEC, BCRA, and results from SIGMA simulation runs (2011).

CHAPTER 3
EVENTS STILL PENDING APPROVAL IN ARGENTINA: A PROSPECTIVE ANALYSIS OF ITS ADOPTION IMPACTS (2011-2022)

The previous section evaluated the impacts, both direct and indirect ones, at the national and global levels of the availability and adoption of GM soybeans, maize and cotton varieties in Argentina. This section estimates the potential impact of the eventual commercial release and adoption of soybeans materials with insect resistance and herbicide tolerance (Bt+HT) combined events (particularly, MON 87701 X MON 89788, also called RR2Y+Bt), as well as a drought tolerance (DT) wheat event.

In order to perform the simulation runs, the SIGMA mathematical model was used in its *ex-ante* version (see Appendix I). In each case, alternative scenarios were defined so as to account for a wide spectrum of situations that could arise during the simulation horizon (10 years), both in the dynamics of adoption paths by farmers and the performance of international markets (i.e., changes in prices).

In all scenarios so defined, one single trait was selected, associated with productivity improvements (due to increase in crop yield and/or reduction in biotic or abiotic losses). The sources of information were highly qualified experts on the performance of the GM materials in field trials. When data included a range of productivity increases, the smallest value was selected so as to minimize the risk of overestimating potential impacts. That is, if the actual (future) performance of the selected agronomic parameters these would deviate from the estimated values, these deviations would be in the direction of a bigger impact rather than a smaller one.

3.1 Insect-resistant and glyphosate-tolerant (Bt+HT) soybeans

3.1.1 Benefits from Bt+HT technology adoption

The basic assumption behind all *ex-ante* simulation runs consists of a 10% increase in the Bt+HT soybeans yield compared to HT soybeans (GTS 40-3-2 event, under study in Chapter 2).

3.1.2 Summary of impacts

Three scenarios were defined and labeled respectively as conservative, moderate and optimistic, by using the same parameters and variables contained in the previous section. Table 3.1 summarizes the values assigned to the variables that define the three scenarios.

Table 3.1. Bt+HT soybeans: Conservative, moderate and optimistic scenarios

SCENARIO	TECHNOLOGICAL LEVEL	AVERAGE ADOPTION TIME (YEARS)	ADOPTION CEILING (% OF AREA)	AREA EXPANSION ANNUAL RATE (%)	PRICE (USD/T)
CONSERVATIVE	Low	6	60	0	300
	Medium	5	70		
	High	4	90		
MODERATE	Low	5	70	1.5	400
	Medium	4	80		
	High	3	100		
OPTIMISTIC	Low	4	80	3.5	500
	Medium	3	90		
	High	2	100		

Source: The authors.

Tables 3.2 and 3.3 show the results of expected impacts for each of the three previously-defined scenarios, in terms of the evolution of production increase, attributable to the adoption of GM technology and gross benefits for the period under study, respectively.

Table 3.2. Estimation of gross benefits from production increase in the 2011/12-2021/22 period attributable to the adoption of Bt+HT soybeans in three scenarios

SEASON	GROSS BENEFITS FROM PRODUCTION GROWTH (M USD)		
	CONSERVATIVE	MODERATE	OPTIMISTIC
2011/12	-	-	-
2012/13	37.3	159.2	483.0
2013/14	95.2	368.7	983.9
2014/15	222.7	724.6	1,620.1
2015/16	447.6	1,175.7	2,206.5
2016/17	734.7	1,582.7	2,614.5
2017/18	991.0	1,854.4	2,859.3
2018/19	1,156.6	2.004.9	3,011.6
2019/20	1,241.8	2.086.8	3,123.9
2020/21	1,281.6	2,138.2	3,221.6
2021/22	1,301.1	2,177.6	3,315.5
Total 2011/12 - 2021/22	**7,509,6**	**14,272,9**	**23,440.0**

Source: The authors, based on results from SIGMA v.2.0 simulation runs (2011).

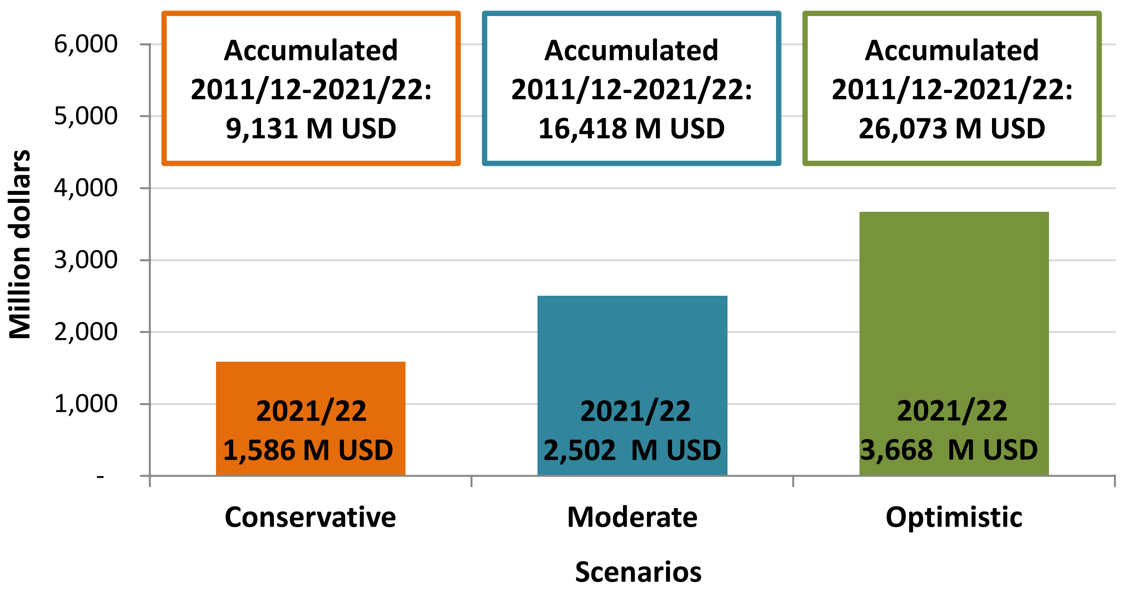
Table 3.3. Estimation of gross benefits from production cost reduction in the 2011/12-2021/22 period attributable to the adoption of Bt+HT soybeans, for three scenarios

SEASON	GROSS BENEFITS FROM COST REDUCTION (M USD)		
	CONSERVATIVE	MODERATE	OPTIMISTIC
2011/12		-	
2012/13	7.4	21.3	53.1
2013/14	19.1	50.7	109.5
2014/15	45.3	103.9	185.3
2015/16	92.7	174.3	256.9
2016/17	155.1	239.9	305.3
2017/18	212.9	283.8	330.7
2018/19	251.5	306.8	342.3
2019/20	271.6	317.3	347.6
2020/21	280.8	322.2	350.4
2021/22	285.1	324.7	352.1
Total 2011/12 - 2021/22	**1,621.6**	**2,145.0**	**2,633.2**

Source: The authors, based on results from SIGMA v.2.0 simulation runs (2011).

Figure 3.1 shows consolidated results (gross benefits due to production increase + cost reduction) for all three scenarios defined at the beginning of this section. The figures shown on the bars represent the values estimated for the last year of the simulation horizon (2021/2022 crop season) and, on the top portion of the chart, the cumulative benefits for the 2011/2012-2021/2022 period.

Figure 3.1. Gross benefits from production increase and cost reduction due to the adoption of Bt+HT



Source: Tables 3.2 and 3.3

3.2 Drought-tolerant (DT) wheat

3.2.1 Benefits from the adoption of DT technology

The expected benefit from the adoption of DT wheat varieties consists of a 28% reduction in losses expected as a result of an alteration in the rainfall system during the cropping cycle, compatible with drought conditions. The assumption was made on the basis that this detrimental climate contingency would happen every 5 years in the period under study (2011-2022).

3.2.2 Summary of impacts

Three scenarios were defined and labeled conservative, moderate and optimistic, by using the same parameters and variables described in the previous section. Table 3.4 summarizes the values assigned to the variables that define the three scenarios.

Table 3.4. DT wheat: Conservative, moderate and optimistic scenarios

SCENARIO	TECHNOLOGICAL LEVEL	AVERAGE ADOPTION TIME (años)	ADOPTION CEILING (% del área)	PRICE (USD/t)
CONSERVATIVE	Low	6	60	150
	Medium	5	70	
	High	4	90	
MODERATE	Low	5	70	250
	Medium	4	80	
	High	3	100	
OPTIMISTIC	Low	4	80	350
	Medium	3	90	
	High	2	100	

Source: The authors.

Table 3.5 shows the results from estimated impacts for each of the three previously-defined scenarios, in terms of gross benefits due to production increase, attributable to the adoption of GM technology for the period under study.

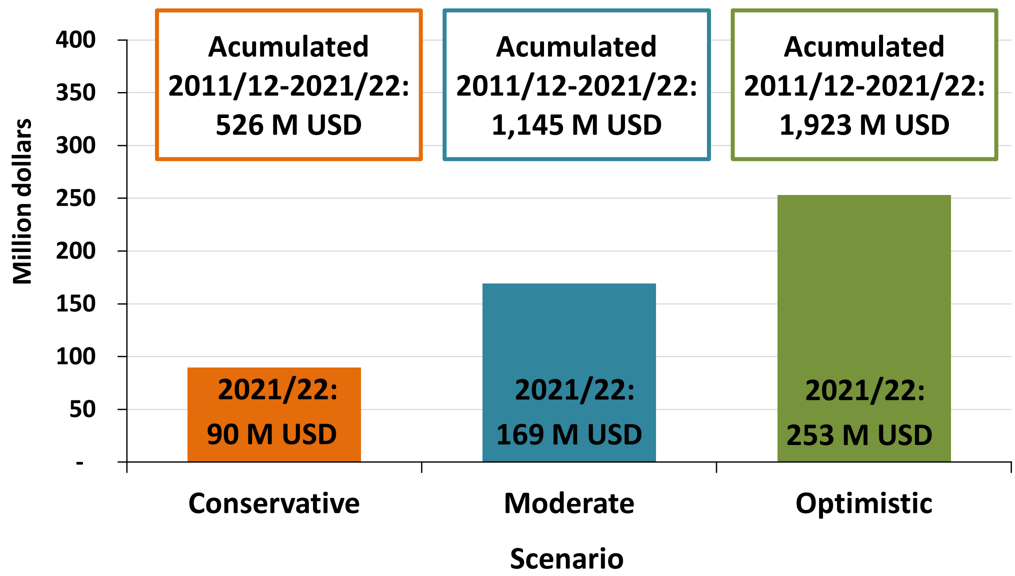
Table 3.5. Estimation of gross benefits from the increase of production in the 2011/12-2021/22 period attributable to the adoption of DT wheat, for three scenarios

SEASON	GORSS BENEFITS FROM PRODUCTION GROWTH (M USD)		
	CONSERVATIVE	MODARATE	OPTIMISTIC
2011/12			-
2012/13	2.8	13.0	43.6
2013/14	7.1	30.4	87.5
2014/15	16.5	60.4	142.5
2015/16	32.6	97.5	191.0
2016/17	52.4	129.7	222.1
2017/18	69.6	150.2	238.1
2018/19	80.4	160.6	245.5
2019/20	85.9	165.5	249.1
2020/21	88.5	167.9	251.2
2021/22	89.8	169.3	252.7
Total 2011/12 - 2021/22	**525.6**	**1,144.6**	**1,923.2**

Source: The authors based on results from SIGMA v.2.0 simulation runs (2011)

Figure 3.2 shows the results (gross benefits due to the increase in production) in the three scenarios defined at the beginning of this section. The figures shown on the bars represent the values estimated for the last year of the simulation horizon (2021/2022 crop season) and, on the top portion of the chart, the cumulative benefits for the 2011/2012-2021/2022 period.

Figure 3.2. Gross benefits from production increase due to the adoption of DT wheat



Source: Table 3.5

CHAPTER 4
SOME ENVIRONMENTAL IMPACTS FROM THE NEW TECHNOLOGIES

Argentina has experienced a true agricultural revolution in the last two decades, and any process of social and productive change having the magnitude such as the one developed in this country throughout this period has both "bright" and "negative" aspects. In this case, the "bright" side of this process is clearly of an economic nature. Magnitudes are beyond every discussion and we could summarize them into the following questions: (i) Is it possible to imagine present-day Argentina without the economic benefits of GM technologies? and (ii) Is it possible to imagine a labor market without the virtuous dynamics of agricultural expansion enabled by such technologies? The bright sides also appear in the meaningful interaction and synergy between GM technologies and no-till farming practices, which have also placed the country at the forefront of advances in the now so-called "sustainable intensification". The "negative" side of this equation consist of the legitimate concerns about the sustainability of the productive processes that have been put in place in Argentina. This section addresses such aspects.

4.1 Synergy between GM technologies and no-till farming practices

The expansion in the cultivation of GM varieties in Argentina has gone, as mentioned in Chapter 2, *pari passu* with a dramatic expansion of no-till farming (NTF). This is particularly meaningful from the viewpoint of environmental impact since, on the one hand, it has enabled to reverse the negative consequences that conventional tilling and plowing practices, prevailing until the beginning of 1980s, have had on the structure and function of Pampean soils (Viglizzo et al., 2010) and, on the other hand, to significantly increase the efficiency standards in the energy balance of agricultural production (Pincen et al., 2010).

NTF began to gain significance in Argentine agriculture by the end of the 1980s, due to the fact that in many of the most important zones of the Pampas region the cumulative effects of soil erosion, resulting from "agriculturalization"[4] based on traditional farming practices, had already began to manifest in the operating results of farms. Such effect on yields and, therefore, on the economic viability of agriculture, together with a greater availability of proprietary farm machinery (as a result of deregulation and opening of the economy) and the reduction in direct costs (due to the elimination of tillage practices), were the optimal platform for the spread of no-till farming and, partly at least, the recovery of lost productivity.

Synergy with herbicide-tolerant soybeans derives from the fact that, as no-till practices shorten the time span between wheat harvest and soybeans planting, they enable the use of short-cycle soybeans as a double crop to take advantage of that window of opportunity and thus, makes a wheat-soybeans double cropping system a feasible option for areas in which that option had not been available before. No doubt, this effect further enhanced towards the end of the 1990s and the beginning of the 2000s by the accelerated drop in the price of glyphosate (it went from 10 US D/liter, by the end of the 90s, to less than 3 US Dollars/liter in 2000). This has been clearly reflected in the evolution of the area under NTF, which went from about 300

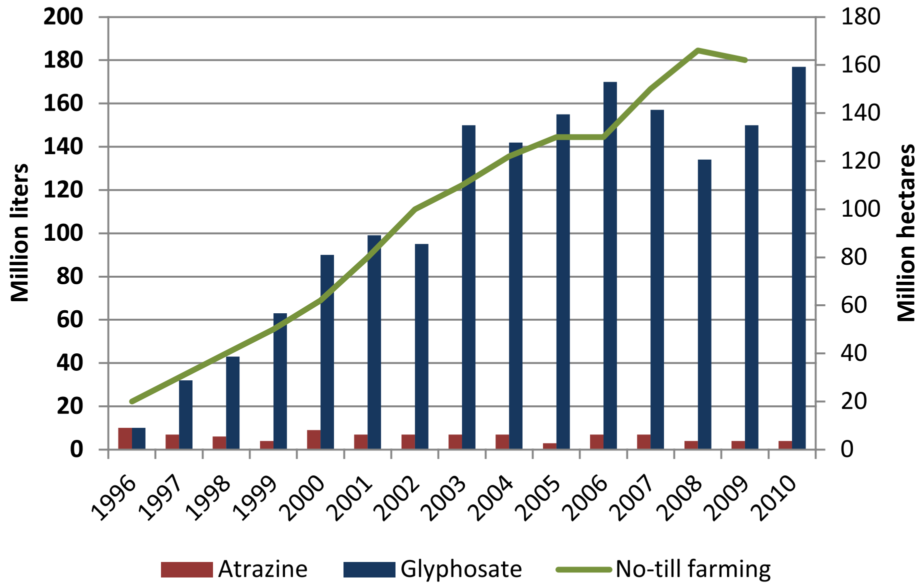
[4] "Agriculturalization" is understood as the substitution for agriculture permanently, instead of crop-pastures rotation systems, which had been the prevailing productive strategy in Argentina until the mid 70´s.

thousand ha in 1990/1991 to nearly 25 million ha at present (for a thorough discussion on such process, see Trigo et al., 2010).

The combination NTF + herbicide-tolerant soybean integrates two technological concepts; one of them consisting of new mechanic technologies that modify the soil-crop interaction, and the other being based on the use of a total herbicide (glyphosate, which causes a lesser environmental impact than other herbicides) that is highly effective to control every kind of weeds and has no residual power[5]. The use of mechanical technologies and total herbicides imply an intensified use of inputs, which is generally described as "hard" (agricultural) intensification. However, as can be seen in figure 4.1, this "hard" intensification is, at the same time, environmentally friendly because it has originated a parallel reduction in the use of other herbicides with higher residual power, such as atrazine.

It is hard to quantify the benefits of this synergy between herbicide-tolerant soybeans and no-till farming, but one cannot ignore the potential positive effects on soil fertility and thus, on present and future land productivity, as well as some other positive externalities, such as its contribution to mitigating the so-called "greenhouse effect". From the standpoint soil organic matter content recovery, Casas (2005) indicates that in no-till farming systems with crop rotations including wheat, maize or sorghum, the annual soil losses are lower than 2t/ha, much lower than the tolerable maximum (10t/ha), and the average amounts under other types of management practices.

Figure 4.1. Evolution of planted area with NTF and type of herbicides used



Source: AAPRESID and CASAFE

Apart from the benefits derived from greater sustainability of production levels due to the recovery of soil fertility, the GM soybeans + NTF package has another type of environmental benefits in terms of fuel consumption, emissions reduction and carbon sequestration, all of

[5] According to Pincen et al. (2010), the persistence of glyphosate in the soil ranges between 12 and 60 days, and it implies a low risk of polluting underground waters. Its toxic effects on animals are mild. It does not bio-accumulate in animal tissues.

which are worth mentioning. According to Brookes and Barefoot (2011), between 1996 and 2009, total fuel consumption in soybeans culture increased by 201.3 million liters (95.1%), going from 211.6 to 412.9 million liters annually, but the average consumption per hectare dropped by 38%, falling from 35.8 to 22.2 liters/ha, which facilitated a carbon dioxide emissions reduction of 5.185 billion kg against the emissions that would have occurred if the 2009 production levels had been based on conventional farming practices. In annual terms, this means the use of 13.5 million liters of fuel less than the volume required under traditional farming.

The same authors report similar effects regarding the carbon sequestration impact resulting from the application of reduced or zero tilling practices. Although it is admitted that data on Argentina are quite inaccurate, by using conservative indicators such as 100 kg/carbon/ha/year for such farming practices, the authors estimate that the resulting cumulative amount of carbon may reach 13.817 million kg, which are equivalent to retaining in the soil 50.707 billion kg of carbon dioxide.

4.2 Other benefits related to environmental and human health

In addition to the above-mentioned aspects, there are other benefits from GM crops associated with the use of pesticides. In this regard, within the World Health Organization classification, glyphosate belongs to the group of herbicides under Class IV toxicity ("virtually non toxic") and, according to 2001 data, even though the introduction of glyphosate-tolerant soybeans implied an increased use of this herbicide –both in volume and number of applications-, it also meant a substantial decline in the dosage and actual use of herbicides having greater toxicity and harmful environmental impact (Qaim and Traxler, 2002).[6] In line with the foregoing, Brookes and Barfoot (2011) compared the herbicide levels required to obtain, by using conventional systems, a weed control equivalent to the one achieved with herbicide-tolerant GM varieties. From such analysis, one can infer that systems based on GM varieties and NTF use herbicide amounts that are slightly greater than the conventional alternatives (2.68 kg/ha against 2.53 kg/ha, respectively). However, as regards the environmental impact of such use, measured as Environmental Impact Quotient (EIQ)[7], the new productive systems represent an improvement compared to the conventional systems. In this regard, the study estimates that in the 1999-2009 period, the total cumulative environmental impact was 12% lower (1,152 million EIQ/ha units) than it would have been under conventional systems.

In the case of maize, reported impacts are much smaller in size, but not in importance. For herbicide-tolerant (HT) maize, the above-mentioned study indicates that there has been a cumulative reduction in herbicide volume of 2.5% (-1,143,000 kg) since 2004, when such technology was introduced in the local market. In EIQ terms, the reduction was 4% for the period 2004-2009. For insect-resistant maize, impacts have been less important, mainly because in Argentina the levels of insecticide use in conventional systems have always been low and, therefore, the comparison with new technologies is not very significant.

Finally, in the case of cotton, the impacts observed in Argentina are very important, and they are in line with what one can notice elsewhere around the world. According to the same

[6] Although this study dates back to 2001, there are no conclusive reasons to believe that this type of relationships have changed significantly with the increased use of GM varieties that has occurred ever since that year.

[7] Developed by Cornell University, the EIQ integrates the amount of active ingredient in the herbicide (in this case) with other effects related to toxicity and exposure of rural workers, consumers, and environment.

study mentioned above, in the case of insect-resistant cotton there has been an estimated reduction in the use of insecticides of 44% under the average of 1.15 kg/ha that is used in the case of conventional varieties; whereas in the cumulative figure since 1998, year in which insect resistance technology was authorized for commercial use, the application of insecticides dropped by 0.47 million kg, which is equivalent to about 29 million units in terms of EIQ/ha. The indicators associated with herbicide-tolerant cotton show a similar performance in the same direction. In the cumulative figure since 2002, the use of herbicides declined by 22% (-1.8 million kg), and EIQ dropped by 27%.

4.3 The impact on soil phosphorus balance in farmland dedicated to growing soybeans

Underscoring the above-mentioned synergy and the benefits specified in the foregoing paragraphs does not mean that we ignore the potential risks implied by the nutrient loss (as a result of the relative low fertilization levels recorded in Argentina), and the impairment of the most fragile ecosystems in Argentina's new Northeastern and Northwestern (NEA and NOA) areas which have gradually been included in soybeans production by the end of this period. In the latter case, the reality tells us that there is little unbiased information available that may enable us to make an analysis of the potential impacts of such process. Regardless of this, it is worth pointing out that, even though soybeans is a core component of present-day "agriculturalization", this process started long before soybeans' burst onto the agricultural scene of Argentina, and that most of the areas where soybean is planted today had already been dedicated to agriculture before. On the other hand, the concerns that are often expressed on how soybeans expansion is threatening biodiversity and the environmental services provided by some particular ecosystems, such as the one known as "Yungas", appear to have been somewhat exaggerated, since changes in farming systems are restricted to the foothills plains, while the sloped foothills and hills, where most of the Yungas' biodiversity and its sources for environmental services are located, are not threatened by the expansion of soybeans (see Grau, Gasparri and Aide, 2005). In the other "new" soybeans growing areas, such as northern Cordoba, Chaco Province, and northern Santa Fe, changes in soil use also seem to come from multiple sources, already being underway before soybeans appeared on the picture (Paruelo and Oesterheld, 2004). Among the most significant sources, once should mention changes in rainfall patterns, which made farming possible in areas that could not be farmed before. Regardless of all these aspects, which should be matter of analysis and discussion, the issue of sustainable productive strategies is extremely relevant.

In a previous paper, Trigo and Cap (2006) estimated the total number of triple super phosphate (TSP) "exported" during the period 1996-2006 as a result of growing soybeans in such soils, since replacement is either non-existent or insufficient. An article published more recently (Colombres, 2011) refers to an increasing concern voiced by institutions like the National Institute for Agricultural Technology (INTA), *Fertilizar* and *Fundación Producir Conservando* on the fact that the system is not sustainable if there is no replacement for nutrients, especially phosphorus. Five years ago, nobody knew when such deficiency would have an impact on partial land factor productivity, that is, on farm yields. According to information given by *Fertilizar* organization, the time has come and there is evidence that soybeans positively responds to phosphorus fertilization (between 500 and 730 additional kg of soybean per hectare, in the core zone) (Colombres, 2011).

Table 4.1 summarizes the estimated evolution of phosphorus exports, denominated in triple super phosphate (TSP) tons and of replacement cost, in million dollars. The total cumulative figure for such process, which is highly detrimental to the chemical fertility of soils, reaches more than 14 million TSP tons. The replacement cost (valued at November 2011 prices in 560 USD/ha) is USD 7.950 billion (the USD 5.5 billion appearing on Table 4.1 represent the total replacement cost valued at prices for each year in the series). Although this is a significant figure, today it only account for 11.62% of total cumulative benefits for the period under study (if it had been replaced annually in the amount required for preserving fertility, such cost would have represent only 8.05% of cumulative gross benefits).

As it is presented, this scenario implies a threat to the most important sub-sectors in terms of foreign currency generation for the country, and it suggests that it is necessary to design and implement as soon as possible a comprehensive policy (incentives, regulation, legislation, or combined instruments) promoting phosphorus replacement in areas planted with soybeans.

Table 4.1. Net exports of phosphorus as soybean (triple super phosphate equivalents) and replacement costs

SEASON	AREA WITH SOYBEAN (ha)	TONS OF EXPORTED TSP	TSP PRICE (USD/t)	REPLACEMENT COST (M USD)
1996/97	6,669,500	458,861	270	123.89
1997/98	7,176,250	493,726	290	143.18
1998/99	8,400,000	577,920	290	167.6
1998/99	8,400,000	577,920	290	167.60
1999/00	8,790,500	604,786	310	187.48
2000/01	10,664,330	733,706	300	220.11
2001/02	11,639,240	800,780	300	240.23
2002/03	12,606,845	867,351	295	255.87
2003/04	14,526,606	999,430	290	289.83
2004/05	14,399,998	990,720	340	336.84
2005/06	15,329,000	1,054,635	320	337.48
2006/07	16,141,337	1,110,524	560	335.00
2007/08	16,603,525	1,142,323	560	560.00
2008/09	18,032,805	1.240,657	560	1,100.00
2009/10	18,343,272	1,262,017	560	490.00
2010/11	18.650,000	1.283,120	560	550.00
Total 1996-2011		**14,198,476**		**5,505.11**

Sources: The authors based on a net extraction (export in the form of soybean) of 68.8 kg/ha of triple super-phosphate (TSP), estimated by Cruzate and Casas (2003); SAGPyA and MAGyP, for planted area and Farm Profit Margins for TSP prices (2011).

Briefly, from the environmental standpoint, the process experienced in the last two decades has significant positive aspects, but it also opens up many questions. This should be no surprise. As mentioned at the beginning of this section, considering the magnitude of the experience in Argentina, this process implies benefits as well as costs. We have addressed those benefits in the preceding chapters and foregoing paragraphs. Associated with such benefits, there are emerging concerns on the advance of soybeans as a monoculture and its implications in terms of "export" of soil nutrients, as well as the advance of agriculture towards new areas with more "fragile" resources outside the Pampas region (Trigo and Villarreal, 2010; Trigo and Cap, 2006; Trigo et al., 2002). All these aspects are relevant and they must be monitored, but there is no doubt that the herbicide-tolerant + NTF package is an overarching alternative regarding the previous situation. However, it is clear that such package alone cannot solve all the sustainability problems implied in the agricultural intensification process.

These issues must be placed in contexts of much broader discussions considering not only actual and potential impacts, but also corrective policies, such as those relating to farm zoning and nutrient replacement promotion, either by way of rotations or chemical fertilization, as well as R&D policies enabling to anticipate not only the inherent and "natural" obsolescence of certain present-day technology propositions, but also the new challenges emerging from the productive model expansion towards new agro-ecological regions, including topics concerning integral soil treatment, as well as disease and pest control, among others.

CHAPTER 5
THE CHALLENGE OF REMAINING AN EARLY ADOPTER

One of the distinguishing traits of the incorporation of GM varieties into Argentine agriculture is the capacity of the country to act as an "early adopter" in the process of spreading GM technologies worldwide. Argentina quickly took advantage of the availability of herbicide-tolerant soybeans, and its incorporation into its agriculture virtually occurred at the same time as the GM technology became available on the US market for which it had been designed. Throughout the period under study, this has allowed Argentina to access plenty of benefits, whether economic and/or other benefits mentioned in this paper.

Although there is no available information enabling to accurately estimate such benefits comparatively with scenarios occurring in other countries, one can make a general consideration based on the evolution of cumulative benefits year after year as a result of the incorporation of the new GM varieties. According to the information shown in Chapter 2, Argentina began accumulating benefits as from the 1996/1997 crop season, whereas other competitors -like Brazil- only started drawing benefits from such new technologies after the 2001/2002 season. Cumulative benefits for Argentina during such period were approximately USD 5.5 billion, a significant amount that must partly be attributed to the new technologies (increased production), and also partly to international prices being much higher. This was due to the fact that by then the market still showed no evidence of the presence of a greater supply on the part of Brazil, something that only started to happen once the use of the new varieties was released, and the dissemination of GM materials led Brazil to surpass Argentina and to currently become the second world GM crop producer.[8] The magnitude of such figures highlights the advantages of being at the forefront of this type of innovative processes and, additionally, the risk –or opportunity costs- implied for the country by a less dynamic GM technology incorporation process than the one recorded in the past.

Despite its methodological simplicity, the foregoing comparison allows for commenting on the costs for a country like Argentina implied the loss of its "early adopter" condition, whatever the reason for its occurrence. In fact, the consolidation of competitiveness in Argentine agriculture and, therefore, of the capacity to generate benefits, essentially depends on the possibility to reduce production costs. As the latter has to do with commodities, it is difficult to cause an impact on prices, even though it is true that in some cases Argentine production, because of its own size, has specific weight when prices are determined by international markets. Within this framework, the earlier new technologies are spread, the greater the benefits reaped; all of which is clearly shown by the data referred to above. If innovations fall behind vis-à-vis the performance recorded by competitors, it would be necessary

[8] Another perspective of the benefits from the "early adopter" condition may be based on secondary information taken from the paper by Brookes & Barfoot (2011), where the impact of GM crops is analyzed at world scale. It is worth clarifying that the methodological approach used in such study is not comparable to the one used in Chapters 2 and 3 of this report and, therefore, the figures for said benefits do not match accordingly. However, it is possible to make some relevant comparisons relating to the size of the benefits that may have existed vis-à-vis Brazil. Pursuant to this comparison, cumulative benefits as of 2009 resulting from the adoption of herbicide tolerant soybeans in Brazil may be estimated at USD 3.2 billion; whereas for Argentina, as from the incorporation of the new GM technologies, benefits would have been USD 9.7 billion. This means a difference of almost USD 6.5 billion, which may be attributable to the "early adopter" condition and the policies that then facilitated the acquisition of such character.

to face the price effects of such processes, without the benefits of lower production costs or greater productivity that may be offered by the new technologies. Drifting apart from the innovation frontier may have self-evident consequences for Argentina today, and in the future these may be bigger and more complex than in the past.

In retrospect, the soybean case did not replicate with the same intensity in other crops, particularly maize, because –for different reasons, mainly linked to protecting access to export markets- the options range was much smaller, both in the number of available technologies and the time taken by events to arrive at the domestic market. However, this was not too important because –for several reasons (maturity of R&D processes, extensions of time, etc.) the dynamics of innovation concerning the incorporation of new GM crops into markets was not very intense. But this does not seem to be the expected future scenario, where GM crops appear to become the “rule” rather than the exception in markets and, in this case, the earlier the new options are included in the country’s productive menu, the greater the benefits to be accrued, as shown by the soybean case in a more than convincing manner.

The significance of the final impact from this process shall, among other things, depend on the fact that GM crops end up consolidating as the market “rule” or not. If they fail to do so, these time lags will remain at the level of anecdotes referring to the dynamics of agriculture and food-related innovation processes. If on the contrary, as conclusive evidence shows quite conclusively, the current developments worldwide are the beginning of a new technology cycle from which a great number of new and specific technologies will emerge (many of them being useful to our agriculture), costs in terms of innovation and competitiveness will be increasingly higher. Along this line, how we can assure the nature of “early adopter” seems to be a strategic topic of discussion, including not only how to expedite the approval processes for new GM technologies, but also –and in a fundamental manner- how to promote new investments in the sector and create mechanisms enabling the huge benefits offered to the society by the new GM technologies to be recycled into new innovation opportunities, economic growth, and social welfare.

REFERENCES

ArgenBio (Argentine Council for Information and Development of Biotechnology), www.argenbio.org, October (2006).

Barsky O (ed.), “El desarrollo agropecuario pampeano”; Grupo Editor Latinoamericano, Colección Estudios Políticos Sociales (1991).

Barsky O y Pucciarelli, A (ed.), “El agro pampeano. El fin de un período”; UBA, FLACSO (1997).

Brookes G and Barfoot P. GM crops: global socio-economic and environmental impacts 1996-2009 (2011), disponible en www.pgeconomics.co.uk

Cap E y González P. "La Adopción de Tecnología y la Optimización de su Gestión como Fuente de Crecimiento de la Economía Argentina", INTA, Instituto de Economía y Sociología. (2004).

Casas R. Disertación ante la Academia Nacional de Agronomía y Veterinaria, Buenos Aires, Argentina (2005).

Chudnovsky D y López A. “La transnacionalización de la economía argentina”; Eudeba (2001).

Ciencia Hoy (revista), “La transformación de la agricultura argentina”, Junio/Julio (2005).

Costamagna O. “Mercado de Semillas. Impacto del Proyecto del Fondo Fiduciario (Regalías Globales)”, Foro de Perspectiva Agroindustrial 2004, Seminario Outlook de la Agroindustria Argentina: El campo como eje de la sociedad argentina; abril (2004).

Cruzate G y Casas R. Balance de Nutrientes. Revista Fertilizar INTA, Año 8, Número Especial “Sostenibilidad”, ISSN 1666.8812, pp 7-13, Diciembre (2003).

Diamante A. “Encuesta Nacional sobre Fitomejoramiento. Informe de Argentina”; Buenos Aires, Argentina

Dros JM. “Manejo del boom de la soya: Dos escenarios sobre la expansión de la producción de la soya en América del Sur”; AID Environment; June (2004).

Elena MG. Ventajas Económicas del Algodón Transgénico en Argentina. INTA. Estación Experimental Sáenz Peña. Chaco. Documento de Trabajo (2001).

Facultad de Agronomía, Universidad de Buenos Aires; “Patrones espaciales y temporales de la expansión de Soja en Argentina. Relación con factores socio-económicos y ambientales”; Informe final LART/FAUBA Laboratorio de Análisis Regional y Teledetección; Noviembre (2004).

Fernández Cornejo J and Caswell M. “The First Decade of Genetically Engineered Crops in the United States”, USDA. Economic Information Bulletin Number 11, April (2006).

Giancola S, Lema D, Penna J y Corradini E(h); “Relevamiento de Gastos en Investigación y Obtención de Cultivares de Trigo y Soja en el INTA.¨, Documento de Trabajo Nº 20. (2002).

Grau HR, Gasparri NI y Aide TM. Agriculture expansion and deforestation in seasonally dry forests of north-west Argentina. Environmental Conservation 32 :140-148 (2005).

Gutiérrez M y Penna J. ¨Derechos de Obtentor y estrategias de marketing en la generación de variedades públicas y privadas¨; Documento de Trabajo Nº 31; Octubre (2004).

Iannone N. Servicio técnico Diatraea en maíz. INTA Pergamino. www.elsitioagricola.com / plagas /intapergamino / diatraea20020502.asp (2002).

IICA, “Informe de Coyuntura. Sector Agroalimentario Argentino”; Instituto Interamericano de Cooperación para la Agricultura, varios Números (2000-2005).

Ingaramo J. “La renta de la tierra pampeana”, Mimeo, Bolsa de Cerales de Buenos Aires, Argentina. January (2005).

INTA, Estudio del Perfil Tecnológico del Sector Agropecuario Argentino (2002).

James C. “Brief 42 Global Status of Commercialized Biotech/GM Crops: 2010”; International Service for the Acquisition of Agri-biotech Applications (ISAAA) Brief Nro. 42. ISAAA: Ithaca, NY (2010)

La Nación. Campo ;“Al Rescate del Medio Ambiente”; 24 de Octubre (1998).

Lazzarini A. "Avances en el Análisis de CNA 2002 y su comparación con el CNA 1988"; Documento de difusión inscripto en el marco de desarrollo de actividades del Proyecto de Beca Profesional de Iniciación "Sistematización y análisis del Censo Nacional Agropecuario 2002"; Co-directores Lic. Víctor Brescia, Ing. Agr. Inés Rivera. INTA. Instituto de Economía y Sociología. Buenos Aires, Marzo (2004).

Lema D. “Algunas observaciones sobre el Nº de EAPs y población rural de los años 90”. Instituto de Economía y Sociología (IES) – INTA (2006)

Llach JJ. Harriague MM. y O’Connor, E. “La generación de empleo en las Cadenas Agroindustriales”, Fundación Producir Conservando, Buenos Aires, Mayo (2004).

López G. “Caracterización y Análisis de la expansión de la soja en Argentina. Transformaciones observadas en la agricultura argentina en los últimos 15 años”; FAO, Documento presentado en el taller (2006).

Manciana EV, Maceira J, De Haro A, Piñeiro M, Trigo E, Martinez Nogueira R. “El Campo a Fines del Siglo XX. Intentos, fracasos y las políticas que vienen”. FORGES. Fortalecimiento de la Organización y Gestión Económica y Social (2008).

Ministerio de Economía y Producción, Secretaria de Agricultura, Ganadería, Pesca y Alimentación de la Nación, Oficina de Biotecnología; “Plan Estratégico 2005 - 2015 para el desarrollo de la biotecnología agropecuaria”; 1ª Ed. Buenos Aires. (2004).

Obschatko E. “La transformación económica y tecnológica de la agricultura Pampasa”; Ediciones Culturales Argentinas, Ministerio de Educación y Justicia de la Nación, Secretaría de Cultura (1988).

Paruelo J y Oesterheld M. Patrones espaciales y temporales de la expansión de la soja en la Argentina. Relación con factores socioeconómicos y ambientales, Buenos Aires, Facultad de Agronomía-UBA (2004).

Penna J y Lema D. Adoption of Herbicide-tolerant Soybeans in Argentina: An Economic Analysis in “The Economic and Environmental Impacts of Agbiotech. A Global Perspective”. Nicholas Kalaitzandonakes (ed). Kluwer Academic/Plenum Publishers, NY (2003).

Pincen D, Viglizzo EF, Carreño LV, Frank FC “La relación soja-ecología-ambiente. Entre el mito y la realidad” en Viglizzo y Jobbágy Expansión de la Frontera Agropecuaria en Argentina y su Impacto Ecológico-Ambiental, Ediciones INTA. 53-63 (2010).

Qaim M and Traxler G. “Roundup Ready Soybeans in Argentina: Farm Level, Environmental and Welfare Effects”, at the 6° Conference ICABR on “Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer”. Ravello, Italia (2002).

Rapela M. et al., “Innovación y propiedad intelectual en mejoramiento vegetal y biotecnología agrícola”, Editorial Heliasta (2006).

Regúnaga M, Fernández S y Opacak G. “El impacto de los cultivos genéticamente modificados en la agricultura argentina”; Programa de Agronegocios y Alimentos, Facultad de Agronomía, Universidad de Buenos Aires; Septiembre (2003).

Secretaria de Agricultura, Ganadería y Pesca (SAGyP) y Consejo Federal Agropecuario; “El deterioro de las tierras en la Republica Argentina”, Buenos Aires (1995).

Trigo E, Chudnovsky D, Cap E y López A. “Los Transgénicos en la Agricultura Argentina: Una historia con final abierto” Libros del Zorzal, Buenos Aires, Argentina (2002).

Trigo E and Cap E, “The Impact of the Introduction of Transgenic Crops in Argentinean Agriculture”, AgBioForum, 6(3): 87-94 (2004).

Trigo E y Cap E. “Diez años de cultivos genéticamente modificados en la agricultura argentina”, ArgenBio, Buenos Aires, Argentina (2006)

Trigo E, Falck Zepeda J y Falconi C. “Biotecnología agropecuaria para el desarrollo en América Latina: Oportunidades y Retos”, Documentos de Trabajo LAC 01/10, Programa de Cooperación, FAO/Banco

Inter-Americano de Desarrollo, Servicio para América Latina y el Caribe, División del Centro de Inversiones, Enero de 2010.

Trigo E y Villareal F. "La innovación biotecnológica en el sector agrícola", en Lucio G. Reca, Daniel Lema y Carlos Flood (eds). El crecimiento de la agricultura argentina. Medio siglo de logros y desafíos, Cap. 7, pp. 161-189, Universidad de Buenos Aires (2010).

Viglizzo EF, Carreño LV, Pereyra H, Ricard F, Clatt J y Pincén D. “Dinámica de la frontera agropecuaria y cambio tecnológico” en Viglizzo y Jobbágy, Expansión de la Frontera Agropecuaria en Argentina y su Impacto Ecológico-Ambiental, Ediciones INTA. 9-16 (2010).

APPENDIX I

SIGMA V 2.2: A SIMULATION MODEL TO ESTIMATE THE IMPACT OF R&D AND DISSEMINATION OF AGRICULTURAL TECHNOLOGY

1. Introduction and general description

The analytical tool used is a dynamic mathematical model (SIGMA), developed by INTA to simulate in a simultaneous fashion the multiple paths by which farmers adopt technology and to estimate the economic impact of it. It can be used either for *ex-ante* and *ex-post* simulations to estimate the effects over production, of the realization of alternative scenarios of R&D and technology transfer, that is, SIGMA calculates the increase in production, with reference to a baseline, attributable to the adoption, at farm level, of technologies either commercially or still in the R&D stage.

The data sets for the runs used in this document were taken from the Technological Profile Study of the Argentine Agricultural Sector (Estudio del Perfil Tecnológico del Sector Agropecuario Argentino) (INTA, 2002), which were collected at the level of homogeneous agroecological zone (HAZ).

The explicit assumptions of the model are the following:

- For each HAZ, farms operate under one of three technological levels (TL): low (LTL), medium (MTL) and high (HTL), each one of them associated respectively with differential practices, inputs and productivity (measured as yields) (see Fig. 1).
- The adoption path of technology by farmers follows a non-linear function (sigmoid), whose parameters are dependent both upon the nature of the innovation and to the socio-economic profile of the target farm population.

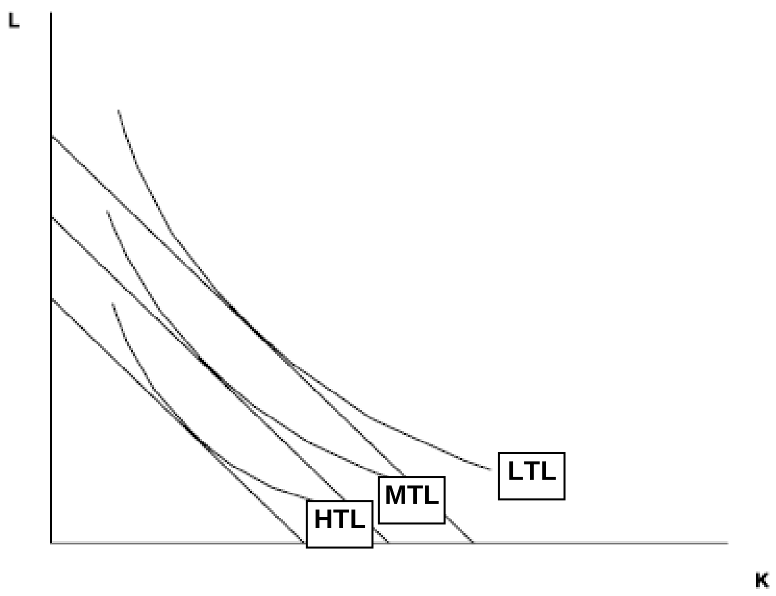


Fig. 1. Schematic representation of three technological levels, as coexisting production functions that generate the same production with three different combinations of inputs, assuming farmers choose the profit-maximizing combination of L and K.

The model's key component is the reconstruction of the process of adoption, by farmers, of technological innovations that shift the isoquant that represents their production functions (as a combination of inputs and factors), achieving a more efficient use of resources, which, in turn, implies a reduction in unit costs and/or an increase in product quality (leading to higher production prices). The most significant implicit assumption that SIGMA makes is that the coexistence both in time and space of the three technological levels (TLs) cannot be satisfactorily explained resorting to the simple (non-restricted) profit maximization model provided by neoclassical economic theory, since according to it, farmers should maximize profit and thus, migrate to the production function represented by the "available" isoquant nearest to the origin (HTL in Fig 1), *i.e*., they all would adopt the profit-maximizing technology. This does not imply that the rationality of farmers is being questioned. Instead, it recognizes the existence of multiple constraints faced by farmers (hard to capture using econometric techniques without detailed and accurate information at farm level), associated with incomplete and/or non-existent markets, as well as of restrictions to the adoption of available technology and its optimum utilization, caused by the undersupply of strictly public goods (such as infrastructure/public under-investments), strictly private ones (such as refrigeration or storage capacity/private under-investments-) or combined ones, such as farm management skills. [9].

2. Data required to run the model (by homogeneous agroecological zone)

2.1 Ex-ante version (used for Bt+HT soybeans and DT wheat in this document)

- Area under production and yield, per technological level, at time t=0 (present time).
- Increase in productivity, reduction in costs or improvement in quality (reflected as a change in production price) resulting from the adoption of technology.
- Adoption ceiling per technological level (maximum percentage or area, per technological level, that could adopt the new technology). It is a function of the restrictions faced by farmers to adopt the technology (*i.e.* diseconomies of scale).
- Size of the area (as a fraction of total area) affected by the problem to be solved by the new technology (or that is to benefit from its adoption).
- Year of availability of the technology.
- Time horizon of the simulation.

2.2 Ex-post version (used HT soybeans and GM maize and cotton in this document)

- Area under production and yield, per technological level, at time t0-x (t0 being present time and x the year of availability of the technology).
- Increase in productivity, reduction in costs or improvement in quality (reflected as a change in production price) and/or expansion of the area potentially suitable for the production of the commodity resulting from the adoption of technology.
- Adoption ceiling per technological level (maximum percentage or area, per technological level, that could adopt the new technology). It is a function of the restrictions faced by farmers to adopt the technology (*i.e.* diseconomies of scale).
- Size of the area (as a fraction of total area) affected by the problem to be solved by the new technology (or that is to benefit from its adoption).
- Observed adoption rate (as a percentage of total growing area) at t0 (end of simulation)

[9] Some of the constraints identified in a previous study are the following: (1) inadequate profitability of the implementation of the new technology; (2) problems with inputs supply; (3) difficulties in obtaining the required labor —in terms of quantity and/or qualification— to implement the new technology; (4) Lack of bank loans at rates consistent with the rates of return from models with the new technology; (5) lack of articulation with agro-industry in order to adjust production to the requirements of the demand (6) lack of knowledge on the part of farmers about the existence and/or implementation of technological alternatives; (7) lack of entrepreneurial attitude (willingness to take risks, implementation of corporate planning practices as well as management and control systems, etc).; (8) lack of professional extension services (public or private); (9) difficulties in marketing higher production volumes (lack of local markets, poor coordination with marketing agents in wholesale markets, transport constraints); (10) Incomplete information on marketing of commodities with no established channels (i.e., new fruits and vegetables, special products responding to specific demands from importing countries, etc).; (11) restrictions derived from farm scale limitations; (12) restrictions resulting from the social organization of production (leasing, sharecropping, hiring, etc).; (13) poor conservation legislation. Cap, E. *et al* (1993). *Perfil Tecnológico de la Producción Agropecuaria Argentina* (Technological Profile of the Argentine Agricultural Production). 2 vol. INTA, Directorate of Strategic Planning. Buenos Aires, Argentina.

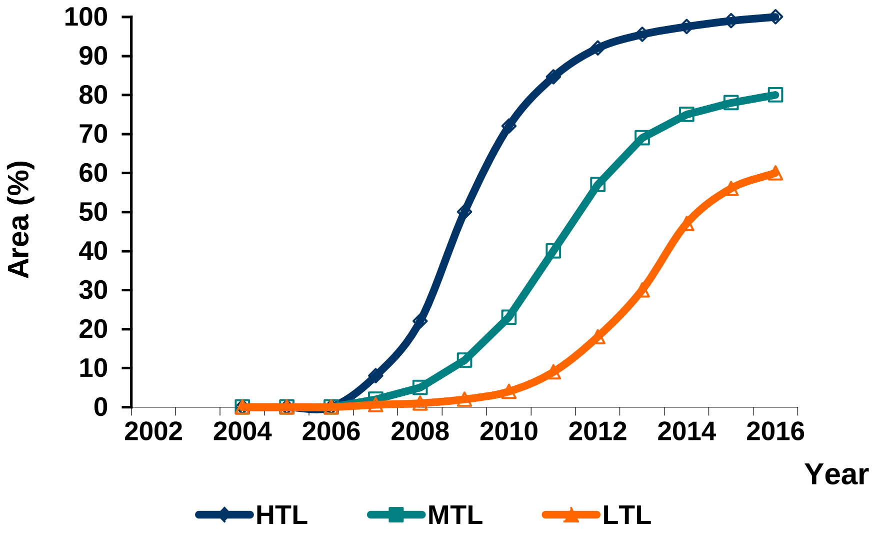


Fig. 2. An example of SIGMA-simulated adoption paths, measured as % of area under cultivation, of a technology available in 2006, by farmers that operate in three technological levels: low, medium and high, with (respectively) increasing adoption rates and diminishing constraints to adoption.

3. Mathematical appendix

To simulate the dynamics of the technology adoption paths, a combination of two functional forms was used; the logistic and the sigmoid functions (the latter as a special case of the former).

The logistic function has the following mathematical expression:

$$\mathbf{P\ (t) = K\ \{1 + me^{-(t-\varnothing)} / 1 + ne^{-(t-\varnothing)}\}} \quad (1)$$

$$\underset{t\to\infty}{\textbf{Limit}}\ \mathbf{P\ (t) = K}$$

The sigmoid function is a variant of (1), by setting **K=1**, **m=0**, **∅=0** and **n=1**, so that:

$$\mathbf{P\ (t) = \ (1 / 1 + e\text{-}t)} \quad (2)$$

$$\underset{t\to\infty}{\textbf{Limit}}\ \mathbf{P\ (t) = 1}$$

The functional form used in the SIGMA simulation model was obtained by setting **m=0** and **n=1** in (1), which implies an expansion of the sigmoid function (allowing for the limit P (t), t → ∞ ≤ 1). This variant also allows fort ∅ to take on values ≥ 0, making it possible to select a point along the **t** axis, at which P(t)´´ changes sign, from + to -. This way, we can choose and modify the adoption half-time, that is, the number of years that elapse until 50% of the area with the commodity adopts the new technology. The final mathematical expression is the following:

$$\boxed{\mathbf{P\ (t) = \ K\ \{1 / 1 + e\text{-}(t\text{-}\varnothing)\}} \quad (3)}$$

The model uses (3) to simulate the dynamics of the technology adoption paths, included in the following empirical formulation:

$$P(t) = \sum_{t=0}^{T} \sum_{i=1}^{3} [\, \beta i \; * \{(Ki / (1 + e^{-(t-\varnothing i)}) * Ait \} \,]$$

where:

P: additional production.

t: time (year)

i: technological level, i ε [1,2,3], where: 1=Low, 2=Medium, 3=High.

β *i*: productivity gap, per technological level, between current and potential values.

Ki: technology potential adoption ceiling ε [0,1].

e: base of natural logs.

∅i: adoption half-time (# of years that elapse before the time at which 50% of the area with TL i adopts the technology under analysis).

Ait: area (in ha) of TLi, at time t (A*it* = f (*Ait-1*, mobility rate[10] ε [0, 1], area expansion rate ε [0, ∞]).

[10] Defined as the percentage of area of TL i (i=1,2) that "promotes" yearly to the next TL (as the result of a combination of determinants, such as the improvement in farm management skills (frequently observed when the farm changes ownership) that leads to higher productivity unrelated to the technology under study. The model sets this rate at 1%/year and it has been included to control for an empirically observed "technical upward mobility" process that could lead to an overestimation of the effects of the adoption of new technologies.

APPENDIX II

Below we quote a description of the methodological approach used for measuring the global impact of the adoption of GM soybeans in Argentina, published in Trigo and Cap (2006):

The elasticity of supply price is a parameter measuring the ΔQ/Δp ratio, an expression which, translated into words, is the fraction at which one expects that the volume supplied by producers will change in the face of an alteration in the grain price, recorded before the planting decision. For example, an elasticity of supply price value of 0.7 means that, for each 1% of price change, supply responds in the same direction, by 0.7% (it increases if the price is higher, and it decreases if the price declines).

The reverse of elasticity –that is to say, the expression ***Δ****p/****Δ****Q, is known as flexibility, and it measures the price responsiveness to changes in the supplied volume. However, econometrists warn about the inconvenience of taking the estimated value of a given elasticity, reversing it, and working on the resulting figure as if it were an accurate estimate of flexibility[11]. Taking notice of this warning, we decided to use for the current fiscal year the elasticity of supply price of soybeans for the USA, the most important world producer, estimated at 0.80 (other values have been quoted for this parameter, in the range between 0.22 and 0.92)[12], but at the same time formulating the assumption that such 0.80 is the real value of the parameter, rather than an estimate. Thus, its reverse value (1.25) shall be considered as the real flexibility-price ratio. If our assumption is correct, we are able to quantitatively estimate the effect that, in the decade under study, additional production originating in Argentina, attributable to the release of glyphosate-tolerant materials, would have had on the international price of soybeans.*

[11] Huang, K. (2006). *A Look at Food Price Elasticities and Flexibilitie*s. Poster Paper. 26th Conference of the International Asociation of Agricultural Economists. August 12-18, 2006. Gold Coast, Queensland, Australia. The problem lies in the fact that the axes on which one minimizes the residual values of the squares are different; quantities in the case of elasticity and prices in the case of flexibility. This means that these two parameters are reciprocal between each other in the economic, but not in the statistical, sense.

[12] Prize, G. *et al* (2003). *Size and Distribution of Market Benefits from Adopting Biotech Crops*. United States Department of Agriculture. Electronic Report from the Economic Research Service. Technical Bulletin Number 1906. November.