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# The Case of Zero-Tillage Technology in Argentina

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2020 Vision Initiative

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A total of 20 case studies are included in this project, each one based on a synthesis of the peer-reviewed literature, along with other relevant knowledge, that documents an intervention's impact on hunger and malnutrition and the pathways to food security. All these studies were in turn peer reviewed by both the Millions Fed project and IFPRI's independent Publications Review Committee.

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[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at www.ifpri.org/pubs/otherpubs.htm#dp.

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## ABSTRACT

Argentine agriculture has undergone significant transformations over the past three decades. After a long period of stagnant production and productivity, starting in the early 1970s, a number of independent but interconnected events fostered a new technological cycle that induced rapid growth in cereals and oilseeds production. Zero tillage and the introduction of genetically modified soybean varieties were key elements of this change, which has significantly increased global supplies of soybeans, an essential food and feed crop. In the process, it has elevated Argentina to a leading position across agricultural commodity markets.

This transformation was the result of an innovative partnership scheme—involving farmers, researchers, extension workers, and private companies—that came together in the 1990s to promote zero tillage, a resource-conserving cultivation practice. This partnership deserves most of the credit for increasing the area under zero tillage from 300 thousand to 22 million ha, between 1991 and 2008. The adoption of zero tillage improved soil fertility by reversing decades of soil degradation, created an estimated 200,000 new farm jobs, and shocked the agricultural commodity markets with additional supplies that helped keep global food prices from escalating.

This paper reviews the institutional process through which these changes came about. It goes on to estimate the benefits attributable to the adoption of zero tillage, not only to Argentine farmers, in terms of increased income, but also to world consumers, measured in terms of savings in food expenditures. Total benefits are estimated at 34 billion dollars.[1]

Keywords: Millions Fed, Food Security, Argentina, Zero Tillage, Soybean

[1] All money figures are US current dollars.

# 1. INTRODUCTION

Technological innovation can sometimes have a global impact on production processes. While some technological innovations affect only a few features of production, a far-reaching innovation may affect the whole production process or even the organizational and economic logic of an entire productive sector—or even of the economy itself.

Technology is an essential element in both the production processes and the economics of agricultural production (Sábato 1971); and technological change—at any level of the production chain—affects economic interactions among all actors within that chain. The innovation of zero-till farming had far-reaching effects on Argentine agriculture and beyond.

Zero-till technology allows the farmer to lay seed in the ground at the required depth with a minimal disturbance of the soil structure. Specially designed farm machinery eliminates the need for plowing and minimizes the tillage required for planting. The introduction of this cultivation technique in the Argentine pampean region generated significant changes throughout the agricultural sector on both relevant dimensions: production and productivity and it triggered changes in productive and commercial structures well beyond the farm gate. The adoption of zero-till practices had implications for the national economy and, given the substantial role of Argentina's agricultural production in world markets, for global consumers as well. Table 1 gives an overview of the cumulative impacts.

**Table 1. Impacts of the adoption of zero-tillage in Argentina**

| | |
|---|---|
| Land under zero tillage cultivation (2008) | 22.3 million (ha) |
| Cost reduction for the farmers in Argentina (1991–2008) | $ 4.7 billion (ha) |
| Increased gross income of farmers in Argentina (1991–2008) | $12.0 billion (ha) |
| Reduction in consumer expenditures Worldwide (1991–2008) | $17.0 billion (ha) |

This paper looks into the process of adaptation and adoption of zero-till agriculture in Argentina, addressing the issues raised by these two questions: (i) What factors have contributed to its adoption and diffusion by farmers? (ii) What has been the economic and social impacts of this set of changes, both at the national and at the world levels? Section two describes the scenario prevailing prior to the introduction of zero-till practices. Section three analyzes the institutional features of the process of innovation, as well as the factors behind its development and consolidation. Section four tells the history of zero-till in Argentina. Sections five and six, as well as the Annex, focus on the impacts of zero-till in Argentina and the assessment of its economic benefits both at the national and international levels. Section seven presents the conclusions drawn from the study.

## 2. THE INTRODUCTION OF ZERO-TILL AGRICULTURAL PRACTICES IN ARGENTINA

During the second half of the last century, Argentine agriculture was on a roller coaster. After an extended period of continued growth during the late 1940s and the early 1950s, the country became one of the main players in world agricultural markets. A combination of climatic events and policy changes reversed this trend, however, ushering in a period of production and productivity stagnation. The lack of technological innovation during this time has been explained in terms of the incentive structure, as farmers minimized the use of commercial inputs as a risk management strategy in a time of macroeconomic instability.

Towards the end of the 1960s and throughout the 1970s, a change in overall conditions marked the onset of a new technological cycle, involving the mechanization of agriculture[2] as well as the use of improved seeds. This development was related to breakthroughs in plant breeding that eventually led to significant production and productivity increases.

It is in this context that the first soybean varieties adapted for cultivation in the pampean region appear. This region is home to about 65 percent of the country's population and hosts close to 140 thousand farms. It covers an area of about 76 million hectares in the central part of the country (including all of the Province of Buenos Aires as well as parts of Córdoba, Entre Ríos, La Pampa, and Santa Fe). The region presents a landscape in which undulating plains predominate and it is endowed with a temperate climate with 300–1000 mm of rainfall. It is mostly dedicated to rainfed extensive production of cereals and oilseeds, as well as livestock (both beef and dairy) and fruit crops. In the "green belts" around the largest cities, however, farming is much more intensive; in these areas, vegetable crops are the most important industry.

Although soybeans had been introduced in Argentina in the early decades of the twentieth century, it was only in the late 1950s that a basic package of agronomic practices for the crop was developed. At that point, commercial cultivation of soybeans began to be of some importance.[3] In later years, the continued expansion of international demand for plant protein became the driving force for the rapid and sustained adoption of soybean cultivation by local farmers. Moreover, the introduction of soybeans opened up a process of technological change and overall improvement in the organization of production, based on a double-cropping scheme, with soybeans following wheat within a single planting season.

This production scheme led to higher farm incomes, but it also demanded a much tighter management schedule to deal with (among other factors) increased climatic risks, higher demands for weed control strategies, and more efficient use of farm machinery (Alapín 2008; Senigagliesi and Massoni 2002). This new scenario created additional demand for technical assistance at the farm level to manage the relatively unknown crop and the greater complexity of the new cropping systems. Expertise was needed to bring all the parts together in an effective way; access to information and knowledge became a key factor in farmers' success.

This process resulted in a major shift in agricultural output: grain and oilseed production went up by more than 50 percent between the early 1970s and the mid-1990s. However, the new double-cropping system took a considerable toll on soil fertility. Due to the tightness of planting schedules—by planting early in the season, the farmer could minimize the risk of early autumn rains affecting the harvest—the usual practice was to burn the stubble of the preceding crop immediately following the harvest. This minimized the fallow period, but it also had a negative effect on soil fertility (through erosion, loss of organic matter, and so on). The practice began to affect productivity negatively, even in the best resource-endowed areas. A 1995 study estimated that about 36 percent of the total area within the region showed signs of degradation; in two of the most important river basins of the provinces of Buenos Aires

[2] For an in-depth discussion of the evolution of Argentine agricultural production and productivity during the post-World War II period, see Barsky 1991 and Manciana 2007.

[3] In fact, the first shipment of Argentine soybeans, destined for Hamburg, took place in July 1962 (Giorda 1997).

and Santa Fe (the Arrecifes and Carcaraña basins), soil degradation was as high as 47 percent and 60 percent, respectively (SAGyP 1995). This situation recalled the relatively recent episodes of soil erosion and productivity decline in the Kazakhstan plains of the USSR, in the early to mid-1960s. It even brought back memories of the 1930s "Dust Bowl" in the United States (that hit Oklahoma, Kansas, Texas, New Mexico, and Colorado), when the rapid but technologically inconsistent expansion of the agricultural frontier made farming unsustainable, triggering social and economic consequences that are still remembered as one of the darkest periods in U.S. agricultural history (Schoijet 2005; Derpsch 1999).

The growing recognition of the effects of these inadequate soil management practices triggered new interest in improved crop management techniques: specifically, a less aggressive approach to soil preparation and planting would provide better protection from soil degradation (and the consequent risk of diminishing productivity). The resulting debate also led to an increasing demand for better information regarding other countries' experiences. Numerous study tours and visits to farm shows were organized, for both agricultural scientists and farmers, setting the stage for the development of reduced tillage technologies (a predecessor of zero-till), and for the eventual introduction of specialized farm machinery for their effective implementation.

The soil degradation that resulted from the wheat-soybean double-cropping system (and the associated practice of burning stubble) thus prompted a change in crop management practices, along with an increasing reliance on technical assistance to adapt imported technologies (Alapín 2008: 27). Public sector agricultural researchers, innovative farmers and extension workers—as well as the associated manufacturing industries (farm machinery, seeds, and agrochemicals)—-became the core of an innovation network.

This network would play a key role in establishing a new agricultural production strategy based on a completely different approach to soil management and conservation: that is, zero-till farming (Ekboir 2002). The various participants, both public and private, shared a common perception of the nature of the problem as well as a strong interest in solving it, facilitating the generation of knowledge and information-sharing within what was at first a rather informal arrangement. This innovation network became a cornerstone of the rapid transformation from stagnation (or even decline) to a rapid *and sustainable* expansion. Local actors—farmers as well as technical assistance providers—played a key role in mobilizing the organizational changes necessary to incorporate the new technologies into existing production systems.[4]

[4] Alapín (2008, 31) highlights how farmers participated in mobilizing the process:

Farmers in the Rosario area started to adopt zero-till practices by adapting conventional seeding machines. Ricardo Ayerza adapted a zero-till potato seeder in Saliqueló and Río Cuarto (Province of Córdoba). In Córdoba there were attempts in the same line and, towards the end of the 1960's, Santos Alzari, a blacksmith in Ascensión in the Junín County, Province of Buenos Aires, built, in response to demands from farmers in the area, a seeding machine adapted to the requirements of zero-till agriculture. (Authors' translation.)

## 3. THE INSTITUTIONAL DYNAMICS OF THE INNOVATION PROCESS

At the international level, concern for resource conservation dates back several decades. In the United States, the Dust Bowl experience of the 1930s prompted the development of reduced-tillage practices to improve soil coverage and to promote sustainable productivity growth. Zero-till technology, however, became possible only when 2-4D (a selective herbicide) became available, as weed control was the main obstacle in switching from existing tillage practices to the new ones. Later, more effective herbicides (such as Paraquat, released in 1961) enabled further development and widespread adoption of zero-till in American agriculture, inducing farm machinery manufacturers to develop new equipment especially designed for zero-till. The United States Department of Agriculture (USDA) and the Universities of Illinois and Kentucky were the leading research institutions that developed the early zero-till technologies; toward the end of the 1970s, they had produced a comprehensive pipeline of innovations—probably the most advanced in the world at that time. In the United Kingdom as well, a significant amount of work was being done on soil conservation and reduced tillage practices, alongside an active adoption process (zero-till reached some 200 thousand ha in 1973). In Latin America, the first efforts were pioneered in Brazil during the 1970s at IPEAME (Instituto de Pesquisas Agropecuarias Meridional, which later became the Empresa Brasileira de Pesquisa Agropecuaria, or EMBRAPA), emphasizing the adaptation of the new technological concepts to local conditions.[5]

Table 2 shows the sequence of events that shaped the development and consolidation of the network behind the massive adoption of zero-till practices in Argentina. The main driving forces were in fact individual initiatives: researchers within the National Agricultural Research Systems (NARS), as well as universities, farmers and technical assistance providers, all of them motivated by widespread and increasing concerns with the sustainability of existing production systems.

As early as 1968, the National Institute of Agricultural Technology (Instituto Nacional de Tecnología Agropecuaria, INTA) began to take notice of the soil degradation problems and took steps to develop more environmentally friendly cultivation practices. This effort materialized in an international project, FAO/SEAG/INTA/ARG/68/526, designed to establish a soil conservation program that would first identify and then discourage the practices that contributed to worsen the problem. This project also played an important role in developing human resources in the field of zero-till agriculture, mainly in England[6] and the United States, as well as in supporting the introduction of specialized zero-till farm machinery (Senigagliesi and Massoni 2002; Alapín 2008).

These early efforts were followed up in 1986 by a much broader initiative, the Proyecto de Agricultura Conservacionista (PAC, the Conservationist Agriculture Project). This program was aimed at developing a response to the already evident land degradation problem—affecting about five million hectares of the best farm land—that had resulted from abandoning the traditional crop-livestock rotation in favor of intensification schemes. This initiative was remarkable as it represented a policy statement by the largest agricultural research institution in the country, on an issue that was already a main concern of both farmers and scientists. It would eventually provide an institutional framework for a whole range of new initiatives. Within PAC, efforts were made to promote crop management techniques aimed at a more sustainable agriculture: a maize-wheat-soybeans rotation; reduced and vertical tilling; nutrient replenishment through fertilization (mainly nitrogen and phosphorus); and integrated pest and weed management. It also facilitated the integration and exchange of information among researchers, extension staff, private technical assistance providers, farmers, input suppliers, and other related institutions (Senigagliesi and Massoni 2002).

Research also went on independently of this institutional effort, both within and outside INTA, by scientists, farmers, technical assistance providers and farm equipment manufacturers (Ekboir 2002). At INTA, as early as the mid-1960s, scientists at the Pergamino Experiment Station started to do research on

[5] For a more in-depth discussion of these aspects, see Derpsch 1999, 79–97.

[6] In 1974 the United Kingdom was the second country after the United States in total area under zero-till agriculture and was a pioneer on research work in the field (Senigagliesi and Massoni 2002).

techniques to reduce soil degradation induced by agricultural practices. This work was later taken up by fellow INTA researchers at the Marcos Juarez Experiment Station. These initiatives were meant to address what they perceived as critical problems limiting agricultural production in the areas of influence of their respective Experiment Stations.

**Table 2. Highlights of zero-till technologies development and adoption in Argentine agriculture**

| Highlight | Year | Events |
|---|---|---|
| Key actors in the innovation network emerge: farmers, agricultural research institutions, researchers and extension workers, and the agricultural inputs manufacturing industry (farm machinery, seeds, and agrochemicals). | 1930s | International awareness of the environmental and social consequences of certain agronomic techniques, prompted by "dust bowl" in the US |
| | 1956 | Creation of the Instituto Nacional de Tecnología Agropecuaria (INTA), as part of the international trend to develop national institutions that can apply global knowledge resources to local problems. |
| | 1961 | Market introduction of the first systemic herbicide (Paraquat, developed in 1955). This led to the intensification of research on zero-till practices. |
| | 1968 | First local efforts to find solutions to soil degradation problems, developed by INTA; not yet directed to zero-till practices. |
| | 1971 | First zero-till experiment in Latin America by the Instituto de Pesquisas Agropecuarias Meridional (IPEAME), in Londrina, Estado de Paraná, Brazil, with cooperation with GTZ |
| | mid-1970s | R & D work on different components of zero-till technology, undertaken by individual researchers (INTA), farmers, and technical advisers. |
| | 1986 | INTA begins to implement the Conservationist Agriculture Program (PAC) |
| Institutionalization of the innovation network | 1989 | Creation of the Asociación Argentina de Productores de Siembra Directa (AAPRESID, Argentine Association of Zero-Till Farmers) |
| Zero-till technology becomes increasingly recognized as a SUPERIOR alternative to conventional tilling | 1990–95 | Increasing adoption and consolidation of the innovation network. |
| Zero-till adoption rapidly increases to become the "industry standard"; AAPRESID emerges as a key player in the innovation network. | 1996–present | Market introduction of the first genetically modified crop (glyphosate-tolerant soybeans). |

Source: The authors, based on cited literature.

In parallel with these activities, many people did experimental work and shared information: farmers, technical assistance providers, and agricultural input and machinery company representatives. Researchers from INTA, for example, worked closely with the farm machinery industry for the purpose of adaptating zero-till equipment to local conditions, without any formally binding agreements. This informal arrangement played a key role in the development of locally-designed zero-till machinery (Ekboir 2002, 7).[7] The expansion of zero-till practices to other crops was similarly initiated through

[7] In highlighting this interaction among private technical assistance providers and local farm machinery firms, Ekboir states:

Several farmers who had participated in field trials in Marcos Juarez began searching for new sources of information. For example, after a conference by Sherly Philips (University of Kentucky), one of the Rosso brothers traveled to the USA to see firsthand what was been done there with regard to zero-till practices and in this trip they realized that for its development to move forward, they needed sowing machines, so they contacted Schiarre (a local firm) to develop a prototype. At about the same time, Agrometal, another local farm machinery firm started to work in a collaborative fashion with the Marcos Juarez research group to start the development of a local design. The same type of interaction took place among other firms, farmers and researchers to informal channels. Although most specialists recommended zero-till only for soybeans (as the second crop in a double-cropping scheme), a group of farmers and extension workers started trials involving other crops, generating the information needed for an even higher adoption of the practice (Ekboir 2002).

At this point, the area under zero-till cultivation was negligible; the basic concepts and the institutional structure that would sustain the coming explosive technological expansion were still being established. The informal emerging network identified problems, tried alternative approaches, and shared information about the results. However, the new approach was still being fine-tuned to local conditions, limiting its appeal to farmers. The situation began to change when glyphosate became commercially available in Argentina, greatly facilitating weed control and overcoming the main obstacle to the adoption of zero-till technology.[8] Against the backdrop of farmers' experience of soil depletion, the availability of an effective weed control alternative, along with the implementation of the PAC by INTA, had set the stage for the launch of a new zero-till innovation cycle.

In this context, the Asociación Argentina de Productores de Siembra Directa (AAPRESID) was created in 1989. Its founding members were mainly medium- and small-scale farmers and technical assistance providers—about twenty people, all of them already involved in the movement to promote zero-till agriculture. The new organization focused on the diffusion and exchange of information regarding zero-till practices. It was set up as an open institution aiming at integrating representatives of all of the stakeholders (though only farmers were eligible to serve on its Board of Directors). The new institution grew very rapidly: within two years, the majority of the key players in the agribusiness sector had become members. AAPRESID became the fulcrum around which the development and expansion of zero-till has continued to evolve until today. Beside its mission of promoting and diffusing the new technology, AAPRESID also acted as lobbying group for its members, working on such issues as access to more favorable bank loans and tax advantages. For instance, in the 1990s the Province of Santa Fe granted tax exemptions for farmers adopting zero-till practices (Alapin 2008).

AAPRESID thus became the institutional face of the innovation network supporting zero-till development and diffusion in Argentina. Alapín (2008: 117) summarized AAPRESID's institutional evolution:

> In the time elapsed since its creation, AAPRESID became an actor that succeeded in bringing together all the interested parties in promoting the (zero-till) technology; and the farmers were, in close interaction with other parties interested in promoting the innovation, the ones that captured the benefits of the new knowledge. (Translation by the authors).

improve the design of farm machinery equipment. (Ekboir 2002, 7. Translation by the authors.)

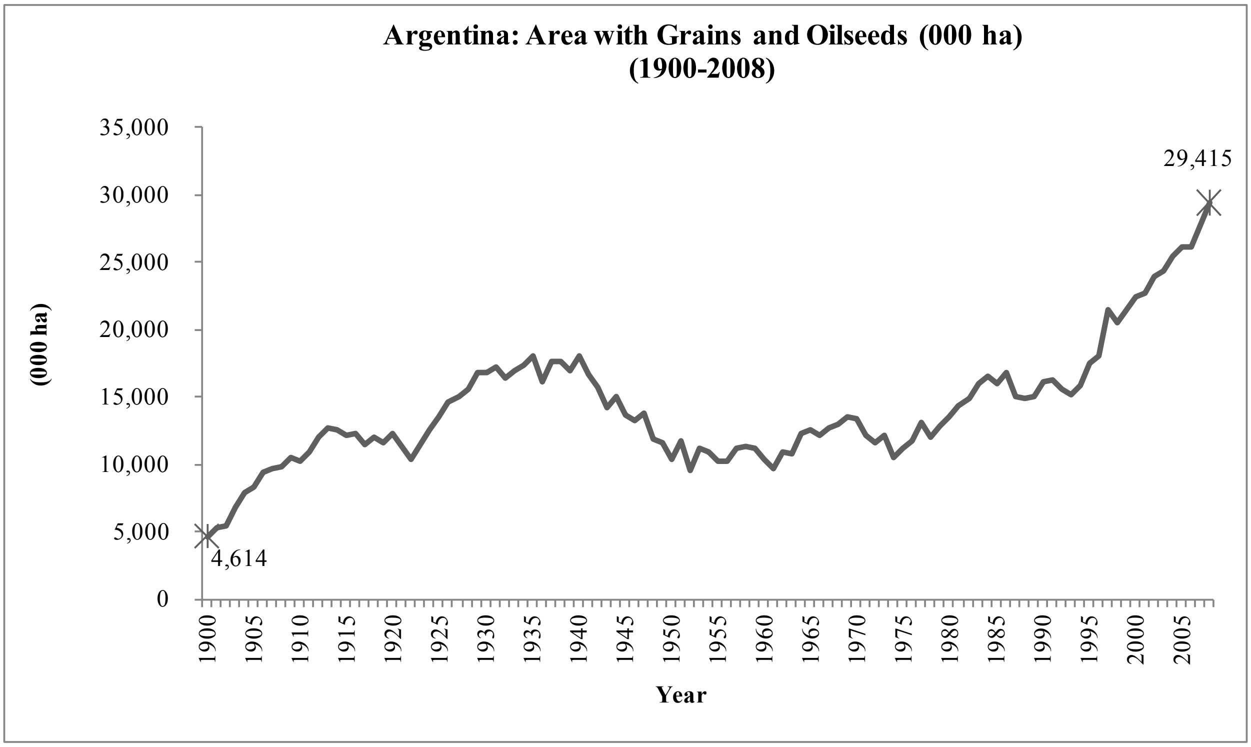
[8] For an extensive review of the characteristics and impact of glyphosate on the environment and on agriculture in general, see Permingeat 2008.

# 4. EXPANSION AND CONSOLIDATION OF ZERO-TILL PRACTICES IN ARGENTINE AGRICULTURE

## Historical Perspective

Figure 1 shows the evolution in planted area (in grains and oilseeds) for the period 1900–2008. Historically, after 35 years of growth, total area peaked in 1935 at 18 million hectares; then began a long phase of decadence, hitting bottom in 1952 at 9.5 million hectares. Agriculture patterns stagnated until the mid-seventies; not until 1996 did Argentina get back to 18 million hectares under cultivation, although this time around that figure was achieved with a different basket of crops.

**Figure 1. Historical changes in planted area (1900–2008)**




Sources: Ferreres 2005 and SAGPyA 2009.

## The Policy Shift

Starting at the beginning of the 1990s, the adoption of zero-till practices picked up speed. Several factors contributed to the consolidation of zero-till farming as the standard for grain and oilseed production in Argentina:

- The new macroeconomic environment of the early 1990s
- The introduction of transgenic soybeans crops with herbicide tolerance
- The reduction in the price of herbicides
- The continued research and promotion efforts

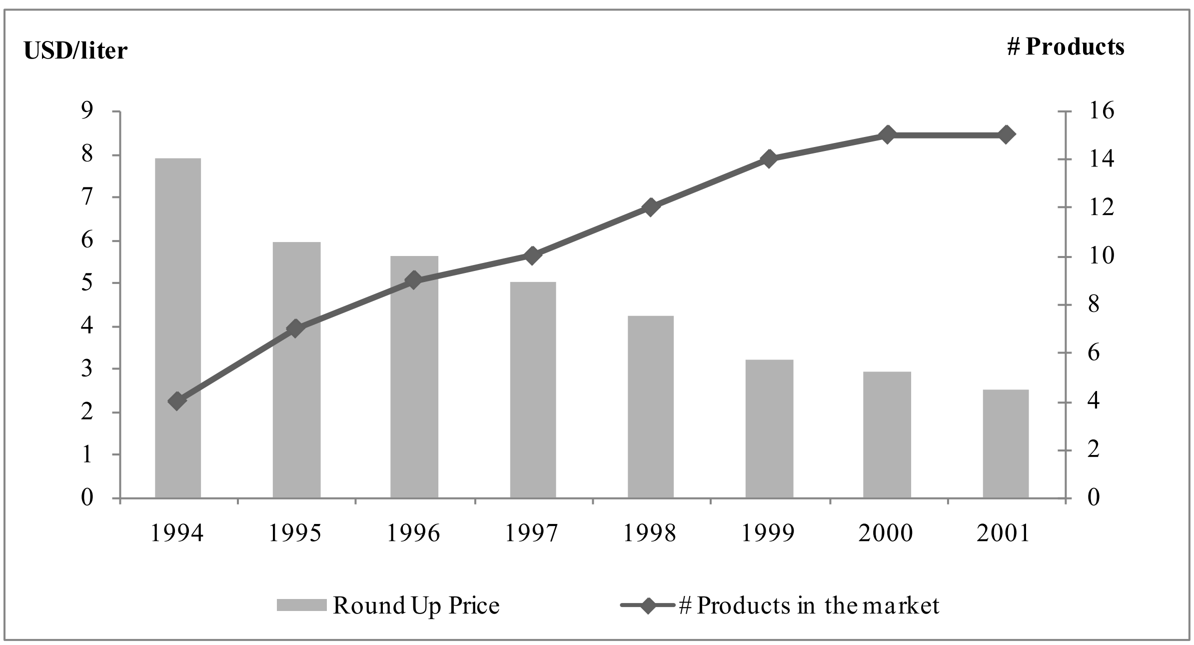
Perhaps most significant was the effectiveness of AAPRESID as a consolidated network, bringing together all relevant stakeholders to share technical and economic information and to promote the benefits of the technology.

The change in the macroeconomic environment involved the elimination of agricultural commodities export taxes and the reduction of import duties on inputs and capital goods. This, together with the deregulation of a number of key markets for goods and services, created favorable conditions for the increase of grain and oilseed production, from 26 million tons (1988–89) to over 67 million tons (2000–2001). Soybeans became the main cash crop in the Argentine export basket.

This expansion took place within a complex international trade environment, with erratic agricultural commodity prices and competition from subsidized exports from the OECD countries. It induced both an increase in planted area—at the expense of livestock—and an improvement in crop productivity through technological change. The increase in total planted area may also account for what appears to have been a partial reversal in the decades-long process of rural-urban migration, with the creation of some 200,000 new jobs in the agricultural sector between 1993 and 1999.[9]

The second key factor was the introduction of genetically modified (GM) materials. The first GM crop formally approved for commercial use was glyphosate-tolerant (GT) soybeans, in 1996. That herbicide, specifically adapted for use with zero-till technologies, facilitated the wheat-soybean double-cropping scheme. Its price declined dramatically with the expiration of the patent and consequent increasing competition from local and foreign manufacturers, helping to consolidate the new production trends.

**Figure 2. Evolution of the price of glyphosate and the number of glyphosate-based products available in the Argentine market (1994–2001)**




Source: Trigo et al. 2002.

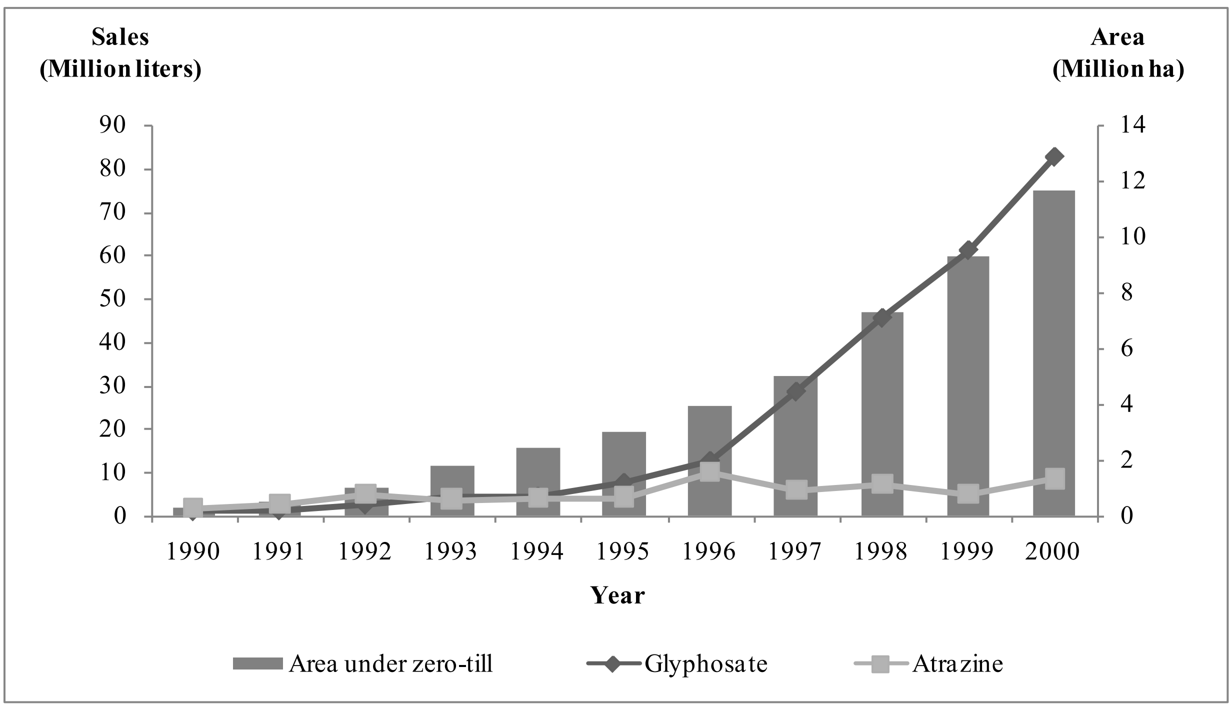
Since it became available to Argentine farmers, the expansion of GT soybeans has been one of the major technological events in the country's agricultural history, with an adoption rate higher than other countries (such as Brazil), and even higher than in its original market in the United States (Galvaõ Gomes 2008). In Argentina, GM soybeans went from less than 1 percent of total planted area in 1996–97

[9] Trigo et al. 2002.

to virtually 100 percent today (www.argenbio.org). At the same time, zero-till systems expanded from about 300 thousand ha in 1990–91 to more than 22 million ha in 2007–2008 (Figure 2).

Possibly the most important factor in the expansion of zero-till was a sort of "virtuous intensification": having the potential for environmentally friendly increases in productivity, through coupling zero-till planting techniques with herbicide-tolerant soybeans. The new mechanical technologies modified the crop's interaction with the soil, moderating the impact of cultivation; while the new full-range herbicides (with glyphosate in the first place) are environmentally neutral, effectively controlling all kinds of weeds without residual environmental effects. The resulting high factor-intensity might be described as a process of "hard" intensification. However, this hard intensification at the same time represents a *virtuous* intensification, by reducing the use of atrazine, a herbicide whose residual action has a negative impact on the environment (see Figure 3). Even with the increased use of agrochemicals, the total use of these products (per hectare of arable land) is still far below that of other countries. The increase in the use of fertilizers during the 1990s was also far below the factor intensity levels recorded in other countries, and seems to have stabilized in recent years (Trigo et al. 2002).

**Figure 3. Evolution of area under zero-till and herbicides used in crop production (1990–2000)**




Source: Trigo et al. 2002.

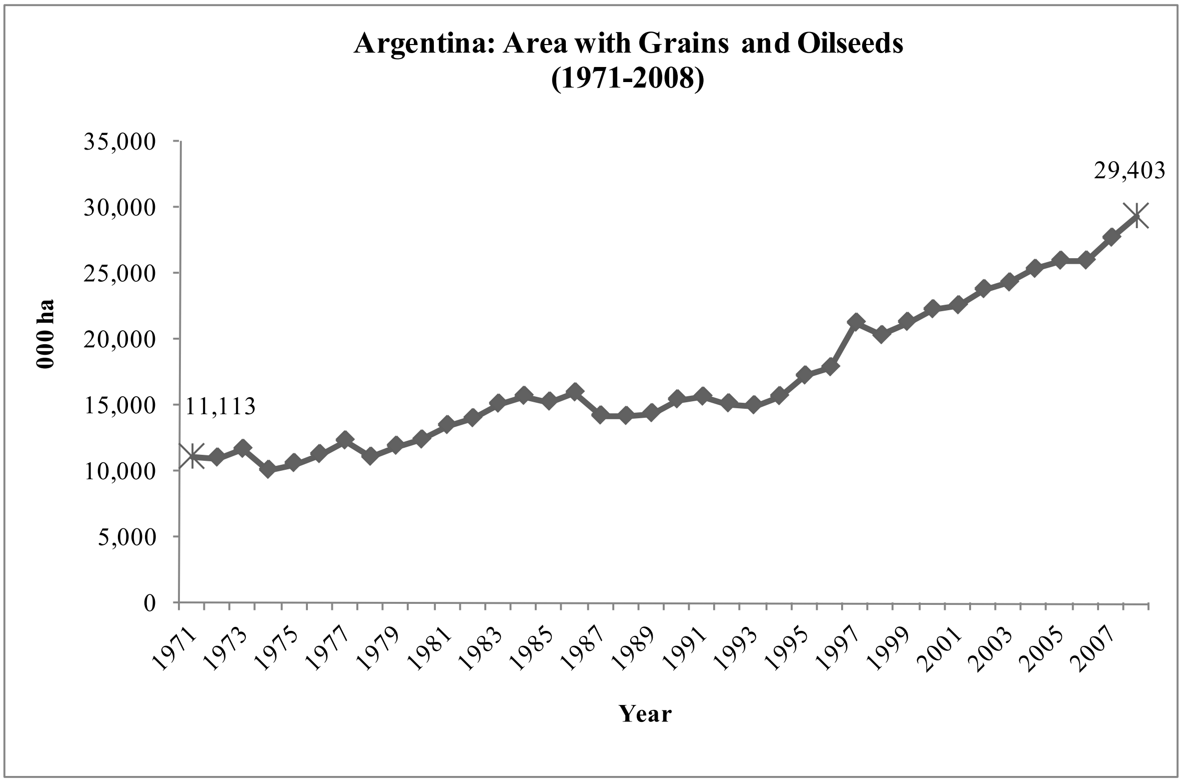
Soybean is a self-pollinated species; consequently, harvested grain can be used as seeds in subsequent plantings without any significant loss of either genetic characteristics or productivity potential, for at least two to three years after the initial crop. This feature has had an impact on the seed market and thus on the price of GT soybean seeds. Under the terms of the 1978 UPOV Convention, farmers are allowed to keep grain to use it as seed for their own use, a practice that has led to the development of an illegal seed market (the so-called "white bag" soybeans), through which seed multipliers also sell uncertified seed of the companies that own the respective intellectual property rights. Some estimates place the market share of this illegal seed at 50 percent or more. This has had a significant effect in driving down the price of GT soybean seed, further promoting the rapid adoption of GM technology and, indirectly, that of zero tillage practices (Costamagna 2004). But on the downside, these illegal markets can be a disincentive to companies who conduct research and development (R&D) on GT soybean, if they are unable to recoup their investments through seed sales in the legal market.

All the factors discussed above help to explain the current dominance of zero-till practices throughout the Argentine grain and oilseed production structure. During the last three decades, all the contributing factors have come together: the initial concerns with diminishing soil fertility; new knowledge of how to improve it; the inputs necessary to implement the new technologies (seeds, herbicides, and machinery); the social networks to promote information-sharing; and an adequate policy environment. The end result can be defined as a "win-win" outcome, with positive economic and environmental benefits for both Argentine farmers and world consumers.

# 5. THE IMPACTS OF ZERO-TILL TECHNOLOGY

The remarkable expansion of total area planted with grains and oilseeds that took place in Argentina during the period 1971–2008[10] represented almost a threefold increase, from roughly 11 million to 30 million ha (see Figure 4). This period was marked by several milestones.

**Figure 4. Expansion of cropped area (1971–2008)**




Source*:* SAGPyA 2009.

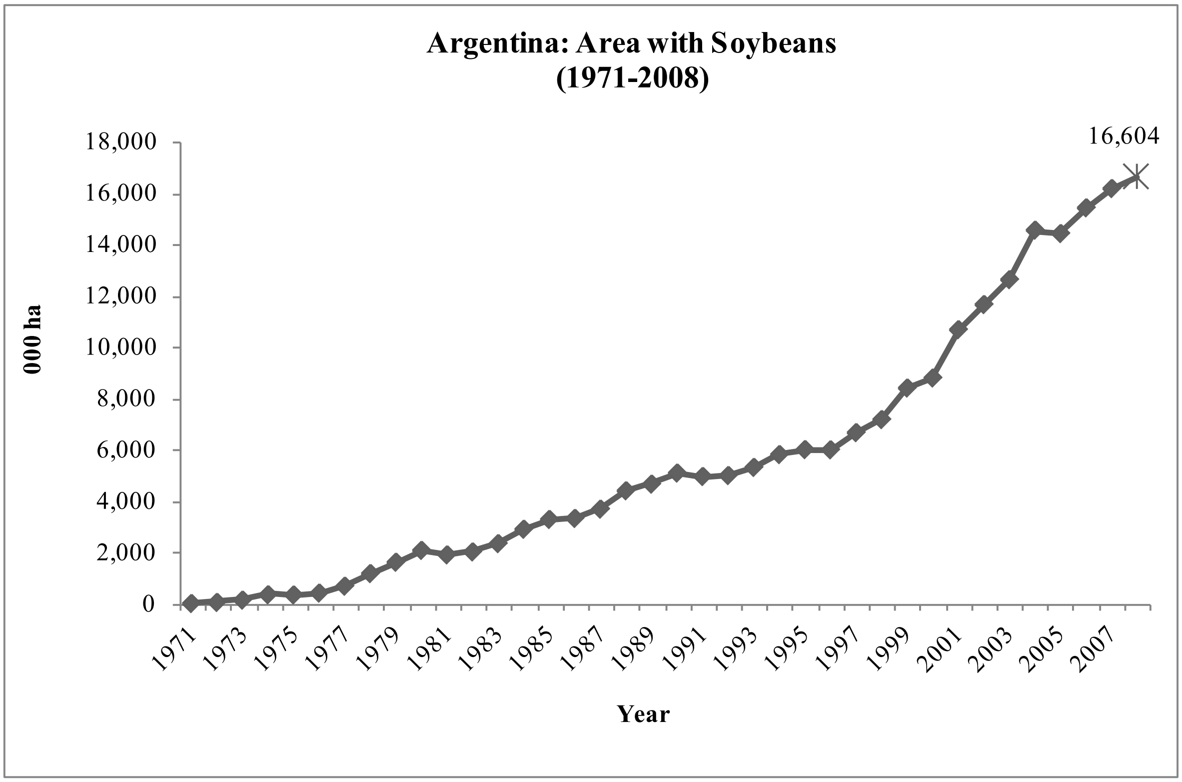
Beginning in 1991, this significant trend was closely associated with the high rate of adoption of zero-till technology, effectively adapted to local conditions (see Figure 5). The expansion of one particular crop, soybeans, played a pivotal role in this process (see Figure 6). The following section assesses the impacts of this expansion, separating out the effects of zero-till from other technologies (such as GM soybeans); detailed computations appear as an annex.

[10] Data for a given crop cycle, such as 1990–91, is here presented as 1991 (harvest year).

**Figure 5. Area under no-till production (1971–2008)**


Source: Based on AAPRESID 2007.

**Figure 6. Area with soybeans (1971–2008)**




Source: SAGPyA 2009.

Some of the effects of the adoption of this technological package are difficult to assess and quantify, as they are related to improvements in the quality of the soil, a key natural resource for agriculture. There is ample empirical evidence related to this particular issue: lower rates of depletion of organic matter, higher moisture-holding capacity, and a consequent reduction (or even reversal) of decades-long degradation processes have been reported (Casas 2003; De Moraes Sá et al. 2004; Andriulo, Sasal, and Rivero 2001; Zaccagnini and Calamar 2001; Sagardoy et al. 2001).

The adoption of zero-till technologies has had other measurable impacts, in terms of changes in income flows of Argentine farmers and as improvements in the purchasing power of global consumers. These two kinds of outcomes—the measurable economic impacts and the less-measurable physical ones—are probably mutually reinforcing.

There is currently an ongoing debate, however, regarding the nature and magnitude of potentially negative impacts of zero-till on the structure of the soils in more marginal areas. These are areas previously not suited for cultivation, that have experienced a major shift in farming systems from (more sustainable) livestock production to relatively intensive (and less sustainable) cropping systems.

## 6. ESTIMATION OF BENEFITS

In this study we will attempt to define the nature and magnitude of the positive impacts of zero-till technology in Argentina, taking into account two dimensions: (i) the supply side, that is, benefits to producers in Argentina; and (ii) the demand side, in terms of benefits to consumers worldwide.

### The Supply Side: Benefits to Producers

We assume that the measurable benefits to producers during the period under analysis came from two sources: the supply shock (above-trend expansion of planted area); and the savings in production costs generated by a reduction in factor use intensity. Both are the result of farmers' adoption of zero-till practices. Details of the methodological approach and actual computations are presented as an annex. The results of these estimations are presented in the following two sections.

#### *Benefits to Farmers from the Supply Shock*

Table 3 presents the benefits to farmers measured as the increase in gross income associated with the expansion of the planted area in soybeans and maize. Those benefits have been remarkable: about 8.3 percent of the total value of these two crops in 2008 is attributable to zero-till induced supply shock; and the cumulative impact is estimated at $12 billion by 2008.

**Table 3. Supply shock: value of additional production of soybeans and maize (1991–2008)**

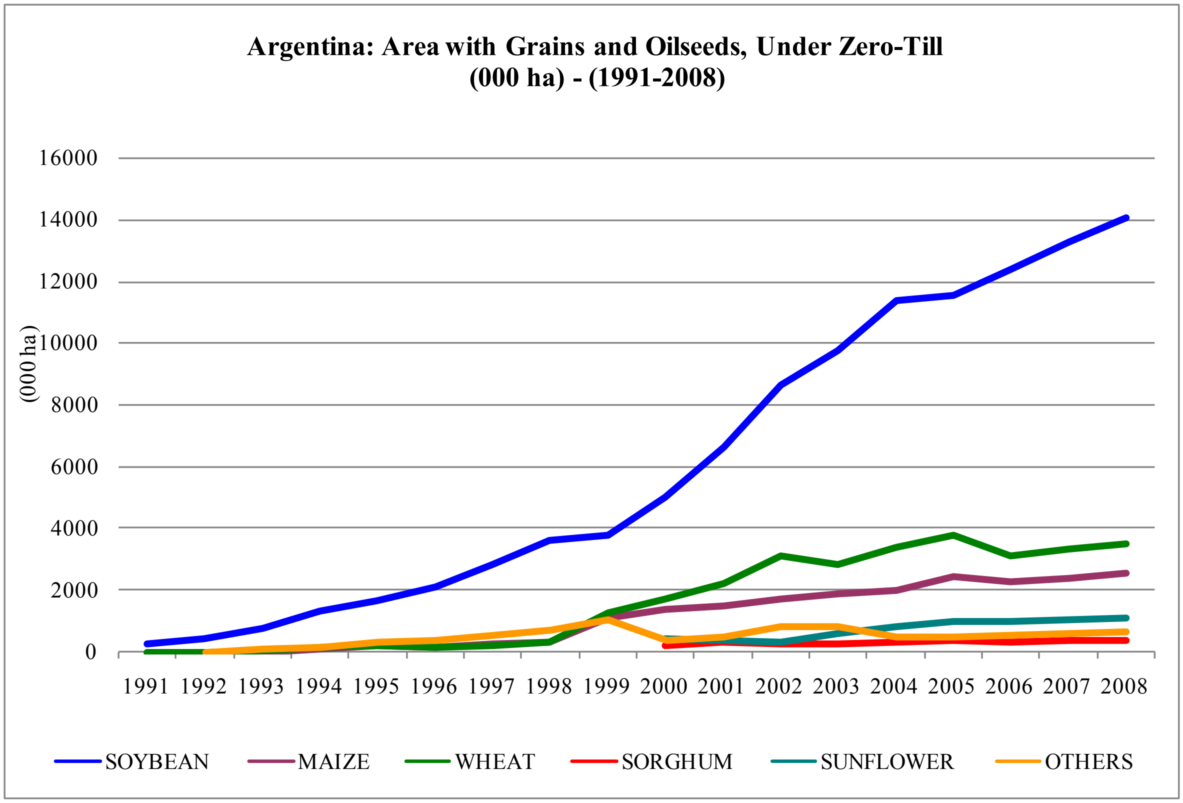
| Year | Argentina: Zero-Till Induced Supply Shock<br>Total Value Of Production Of The Additional Output Of Soybeans + Maize<br>(Million US current dollars; 1991–2008) | | | |
|---|---|---|---|---|
| | Soybeans | Maize | S + M | % of TVP due to zero-till shock |
| 1991 | 31 | 16 | **47** | **1.5** |
| 1992 | 62 | 36 | **98** | **2.8** |
| 1993 | 93 | 54 | **148** | **4.0** |
| 1994 | 121 | 72 | **193** | **4.9** |
| 1995 | 151 | 107 | **258** | **6.1** |
| 1996 | 229 | 148 | **377** | **7.2** |
| 1997 | 227 | 138 | **365** | **7.2** |
| 1998 | 304 | 190 | **494** | **8.0** |
| 1999 | 245 | 173 | **418** | **8.7** |
| 2000 | 278 | 178 | **455** | **8.7** |
| 2001 | 310 | 197 | **507** | **8.5** |
| 2002 | 397 | 271 | **668** | **9.0** |
| 2003 | 552 | 325 | **877** | **8.9** |
| 2004 | 526 | 355 | **881** | **8.8** |
| 2005 | 600 | 379 | **979** | **9.1** |
| 2006 | 637 | 447 | **1,083** | **9.6** |
| 2007 | 1,020 | 787 | **1,807** | **9.7** |
| 2008 | 1,473 | 898 | **2,371** | **9.3** |
| 1991–2008 | **7,255** | **4,773** | **12,027** | **8.3%** |

Source: Cap 2009, based on SAGPyA 2009.

*Benefits to Farmers from Lower Production Costs*

As a side effect of the transformation of soybean cultivation, important crops such as sunflower and wheat (as well as others) also showed significant rates of adoption of zero-till practices (Figure 7). For these crops, however, there was no concurrent growth in cultivated area; in fact, sunflower cropping evolved in the opposite direction. Nevertheless, the new technology brought about a positive change in the cost structure for all crops; these savings can be counted as an innovation-induced benefit to farmers.

**Figure 7. Area under no-till, by crop (1991–2008)**

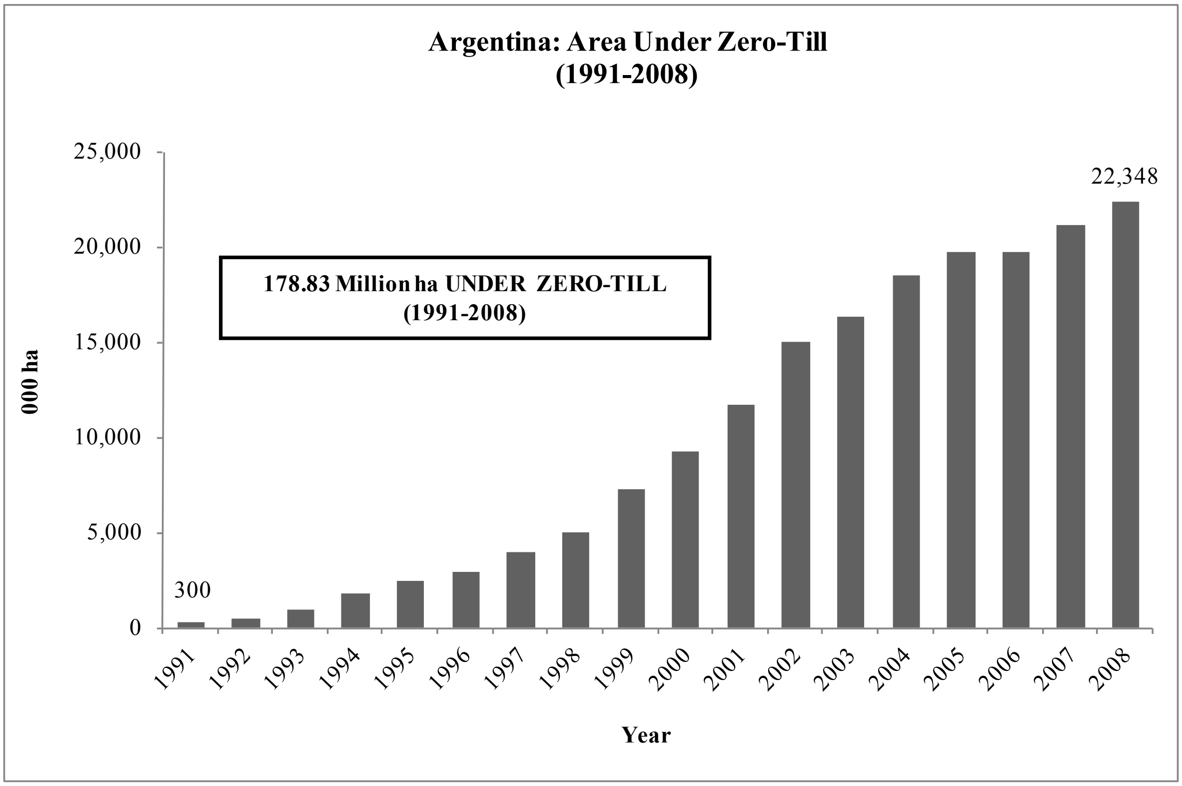



Source: AAPRESID 2007; Cap 2009, based on AAPRESID 2007 and SAGPyA 2009.

The savings benefit to producers is defined as the cumulative savings from lower costs of land cultivation and crop production from zero-till practices. These savings have been estimated at 1.5 UTA (Agricultural Tilling Unit).[11] With a total of almost 179 million ha planted under zero-till since 1991, the cumulative savings amount to $4.7 billion (see Figure 8 and Table 4).

[11] Márgenes Agropecuarios 2009. UTA is the acronym for Agricultural Tilling Unit, an index that compiles the average cost of inputs and labor needed to crop one hectare of farmland, from land preparation to harvest.

**Figure 8. Total area under no-till**




Source: AAPRESID 2007 and Cap 2009.

**Table 4. Cumulative savings from zero-till**

| YEAR | Argentina: Area under zero-till* (ha) | UTA Annual Averages** (USD/ha) | Total Cumulative Savings (M USD) |
|---|---|---|---|
| 1991 | 300,000 | 17.37 | **7.8** |
| 1992 | 500,000 | 16.87 | **12.7** |
| 1993 | 970,000 | 14.86 | **21.6** |
| 1994 | 1,810,000 | 14.86 | **40.4** |
| 1995 | 2,440,000 | 15.72 | **57.5** |
| 1996 | 2,970,000 | 17.55 | **78.2** |
| 1997 | 3,950,100 | 19.02 | **112.7** |
| 1998 | 5,000,000 | 19.20 | **144.0** |
| 1999 | 7,269,500 | 19.20 | **209.3** |
| 2000 | 9,250,000 | 19.21 | **266.5** |
| 2001 | 11,660,000 | 19.07 | **333.6** |
| 2002 | 15,000,821 | 11.21 | **252.2** |
| 2003 | 16,351,212 | 15.18 | **372.4** |
| 2004 | 18,496,446 | 15.65 | **434.3** |
| 2005 | 19,683,172 | 16.09 | **475.1** |
| 2006 | 19,719,436 | 15.99 | **473.0** |
| 2007 | 21,110,471 | 19.63 | **621.5** |
| 2008 | 22,348,159 | 23.74 | **795.9** |
| 1991–2008 | **178,829,316** | **17.25** | **4,708.6** |

*Source: AAPRESID 2007 and Cap 2009.

**Source: AACREA 2009.

## Benefits to Consumers

The benefits to consumers were estimated indirectly, from the price effect of the increase in agricultural output. Zero-till technology in Argentina is associated with two internationally-traded feed grains, soybeans and maize. Soybean production is almost entirely (95 percent) exported.
We estimate the accumulated savings by consumers worldwide for the period between 1991 (the initial adoption of zero-till practices in Argentina) and 2008. (See Annex Tables A1 and A2 for details of the methodological approach and actual computations for soybeans and maize.) A summary of the results is presented in Table 5.

**Table 5. Change in consumer expenditures on soybeans and maize from adoption of zero-till (1991–2008)**

| YEAR | SOYBEANS | MAIZE | S + M |
|---|---|---|---|
| 1991 | -39 | -27 | -66 |
| 1992 | -77 | -60 | -137 |
| 1993 | -117 | -91 | -207 |
| 1994 | -151 | -120 | -272 |
| 1995 | -188 | -179 | -367 |
| 1996 | -286 | -247 | -533 |
| 1997 | -284 | -230 | -514 |
| 1998 | -380 | -317 | -697 |
| 1999 | -306 | -288 | -595 |
| 2000 | -347 | -296 | -643 |
| 2001 | -387 | -329 | -716 |
| 2002 | -496 | -451 | -948 |
| 2003 | -690 | -542 | -1,232 |
| 2004 | -658 | -591 | -1,249 |
| 2005 | -750 | -632 | -1,382 |
| 2006 | -796 | -744 | -1,540 |
| 2007 | -1,275 | -1,311 | -2,586 |
| 2008 | -1,841 | -1,496 | -3,337 |
| 1991–2008 | **-9,069** | **-7,954** | **-17,023** |

Source: Cap 2009.

Note: All figures are million current U.S. dollars.

## Total Benefits

Table 6 presents a summary of total estimated benefits, based on the estimates presented in the previous section. The total estimated benefits derived from zero-till practices in Argentina amount to $33.76 billion, including impacts on both production and consumption. On the supply side, these benefits (over the 1991–2008 period) include some $12 billion worth of additional gross income, and $4.71 billion worth of savings attributed to the reduction in operating costs for Argentina's farmers. On the demand side, $17.02 billion was saved by consumers worldwide, as an effect of lower market prices for both agricultural commodities.

**Table 6. Summary of impacts of zero-till in Argentina (1991–2008)**

| | |
|---|---|
| Increased gross income of farmers in Argentina | 12.03 |
| Cost reduction for farmers in Argentina | 4.71 |
| Reduction in consumer expenditures worldwide | 17.02 |
| Total | 33.76 |

Note: All figures are billion current US dollars.

Note that the benefits computed for the supply side are likely overestimated. Other technologies involved in the production process (such as improved varieties, new inputs, and more efficient management) have a share in the impact that is difficult to separate out. Moreover, the estimate does not take into account the value of the forfeited production that was displaced (mostly low productivity livestock production), a value that is difficult to assess owing to the high heterogeneity of the agroecological and microeconomic parameters. Nevertheless, the magnitudes involved would probably withstand any sensitivity analysis performed on the results. Even if the results on the supply side were overestimated by as much as fifty percent, total benefits would be reduced by just 23 percent, from $33.76 billion to $26 billion—still a very significant figure.

## 7. CONCLUSION

The results presented in this study tell an impressive success story, centered on the set of technologies that came to be known as zero-till farming. These technological innovations were initially conceived to internalize the negative externalities induced by conventional tillage by reversing the damage to the physical and chemical structure of the soil, thus addressing a threat to the long-term sustainability of agricultural production.

According to the estimates presented in this paper, a total of $33.76 billion—in savings and additional earnings—can be attributed to this set of innovations, as developed and adapted for Argentina's agroecological conditions and effectively adopted by Argentine farmers. These are measurable, positive impacts of the development, adaptation, diffusion, and adoption of a specific set of agricultural production technologies.

Beyond the quantitative story is the story of the social process that brought about the transformation. A very diverse set of stakeholders—farmers, research institutions, technical assistance, and the agricultural inputs and farm machinery industry—came together as an innovation network. Their work evolved from the identification of the problem to the development of the technical alternatives, generating not only an information exchange mechanism but also the microeconomic conditions and the policy environment to support the process of change throughout its entire cycle.

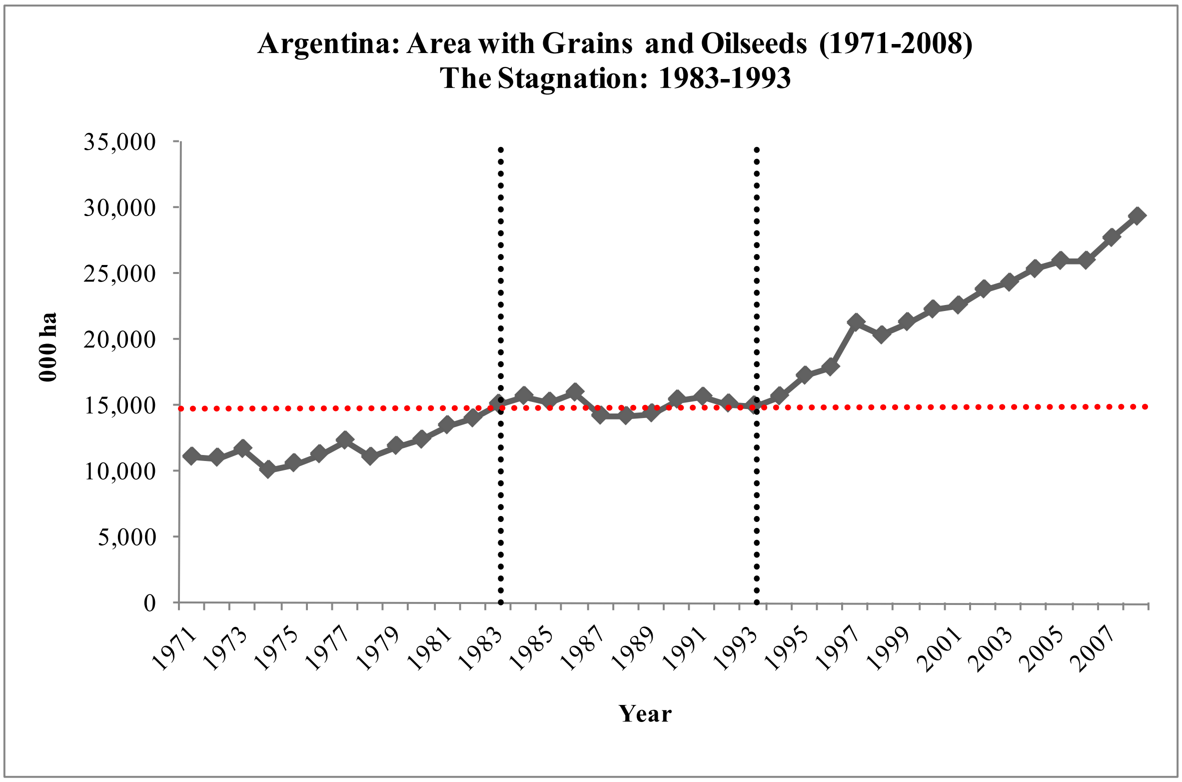
# APPENDIX: MEDTHODOLOGICAL NOTES AND CALCULATIONS

## Estimation of the Benefits to Farmers

### *The Supply Shock*

Since the onset of the zero-till era in 1991, marked by the first 300 thousand ha of crops using that technology, total area in grains and oilseeds rapidly doubled from 15 to 30 million ha. It is quite possible that, if this technology had not been made available to farmers, total cultivated area would have remained at the initial level (15 million ha); in fact, total planted area had been virtually stagnant for roughly the preceding decade, from 1983 to 1993 (see Figure A1).

**Figure A1. Area in grains and oilseeds showing stagnant decade (1983–93)**

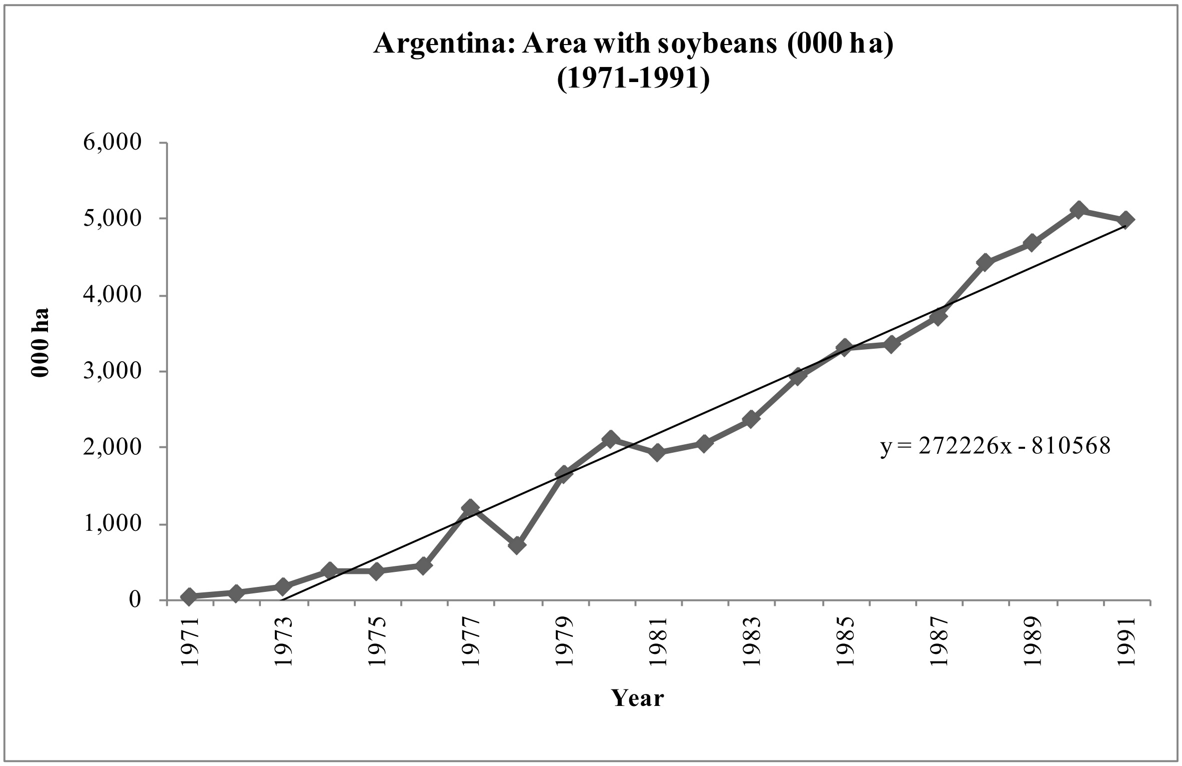



Source: SAGPyA 2009.

*The Impact on Soybean Production.* The stock of land suitable to be planted with soybeans has increased in two distinct ways: the expansion of the agricultural frontier into marginal areas previously not suited to this crop; and the increase in double-cropping (sowing soybeans right after wheat is harvested). Double-cropping constitutes a sort of "virtual" expansion of the stock of arable land, since the same plot is utilized twice in one year. This applies to the entire 1991–2008 period (see Figure A1), but especially to the period beginning in 1997, with the introduction of GT soybeans.

The history of zero-till and the expansion of crop area in Argentina consists of two stages. The first stage covers the period 1991–97. Note, however, that the diffusion of the zero-till technological package in fact had its beginnings in the late 1970s; by 1991, the expansion of soybeans was already significant, at 272 thousand ha/year for the period 1971–91 (see Figure A2).

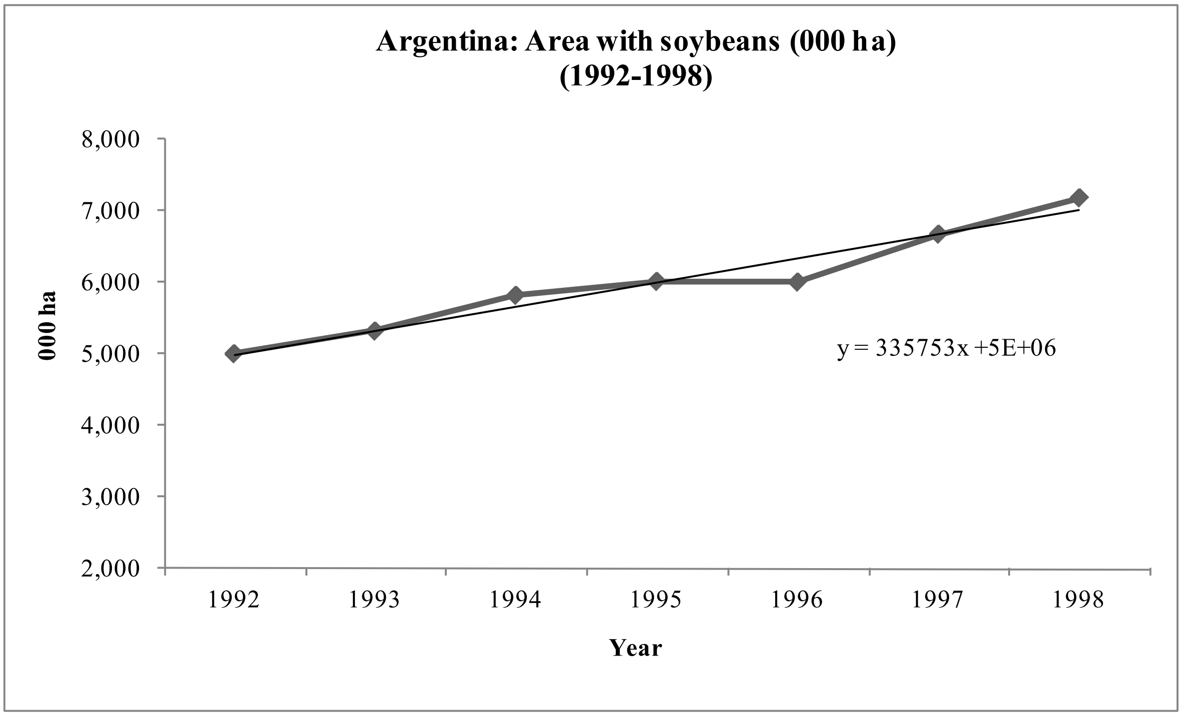
**Figure A2. Argentina: Area with soybeans (1971-1991)**




Source: SAGPyA 2009.

The period between 1991 (the start of the adoption in a significant scale of zero-till) and 1998 shows an even faster expansion of the area planted with soybeans, at 336 thousand ha/year (see Figure A3).

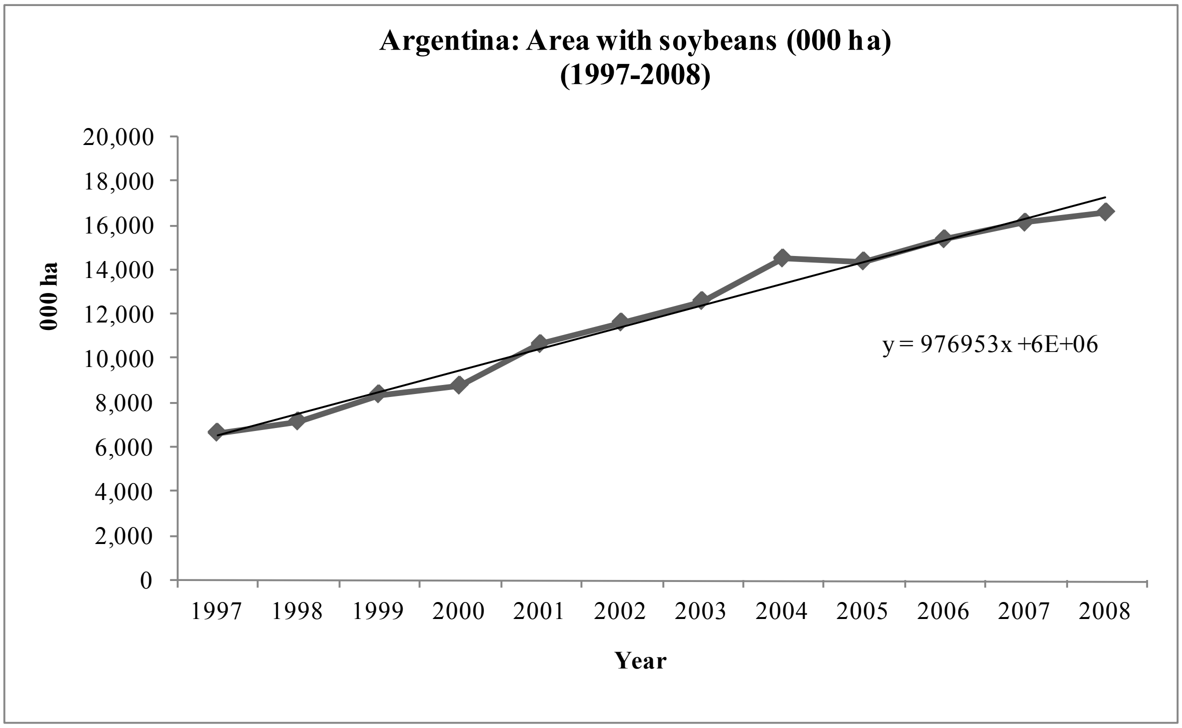
**Figure A3. Argentina: Area with soybeans (1992-1998)**




Source: SAGPyA 2009.

The second stage (1997–2008) evolved from the release in 1996 of GT soybeans for commercial use in Argentina (almost simultaneous with its release in the United States). This triggered an acceleration of the rate of expansion of the area planted with soybeans—in fact, almost tripling it. These two technologies, zero-till and GT soybeans, implemented as one package, became a most effective combination. For the 1997–2008 period, the area with soybeans trended upwards at a rate of 977 thousand ha/year (see Figure A4).

**Figure A4. Argentina: Area with soybeans (1997-2008)**



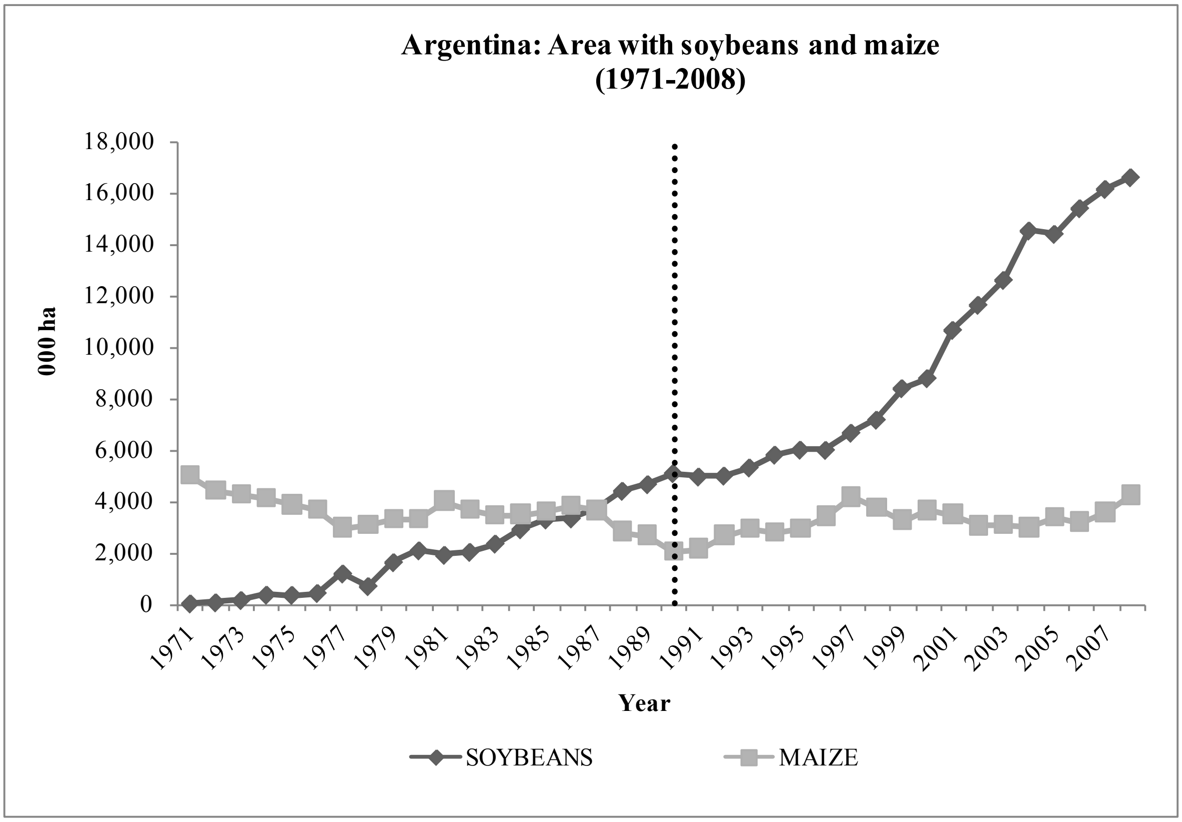

Source: SAGPyA (2009)

For the purpose of this study, it was assumed that the pure effect of zero-till on soybean planted area is effectively captured by the difference between the expansion rate during the period 1992–98 (336 thousand ha/year) and that of the previous period, 1971–91 (272 thousand ha/year). The result comes to some 64 thousand ha/year.

It was further assumed that, if the GT soybean varieties had not been released commercially in 1996, these 64 thousand hectares/year would have been added to the stock of land planted with soybeans from 1997 to 2008, as an effect of the continuing adoption of zero-till practices by farmers (net of the synergy effect of the zero-till + GT soybeans technological package).

*The Impact on Maize Production.* As mentioned above, soybean cultivation was initially adopted in Argentina in the late 1960s, but the area planted became worthy of statistical attention only in 1971, when it reached 37.7 thousand hectares. From that point until 1991, the evolution of soybean and maize cultivation mirrored one another (see Figure A5): the increase in soybeans was, for the most part, in substitution for maize.

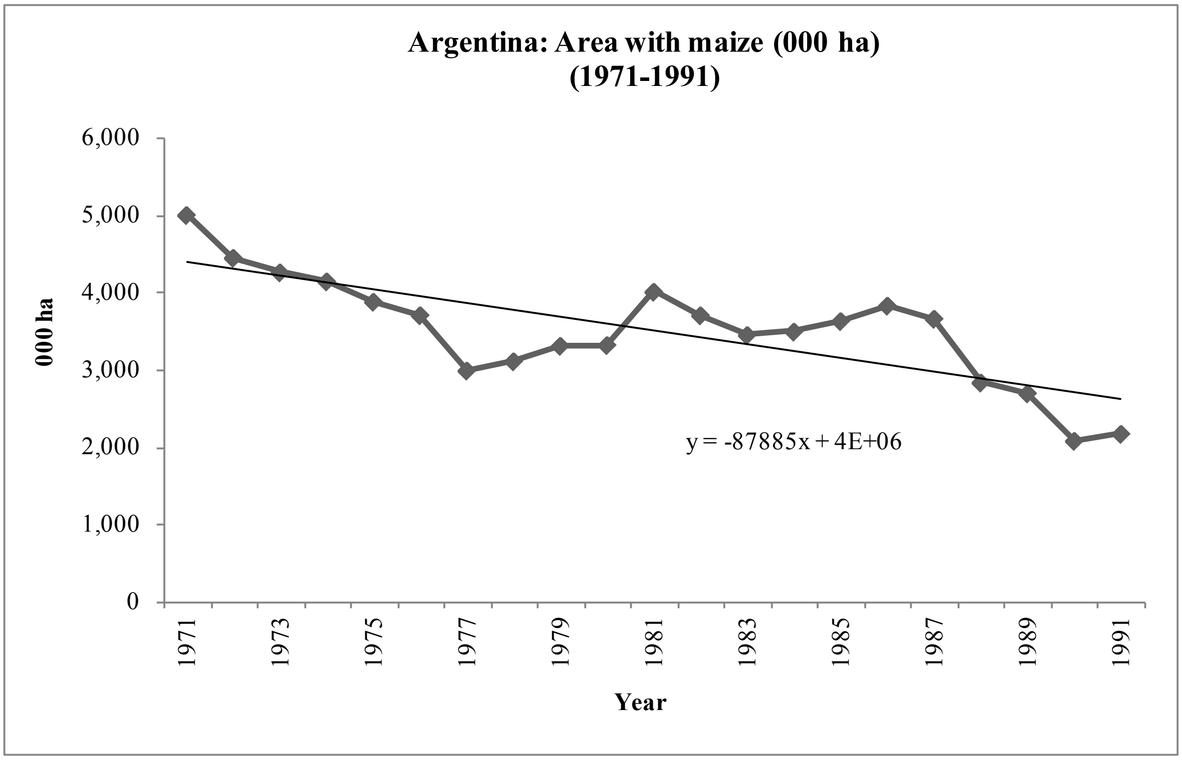
**Figure A5. Argentina: Area with soybeans and maize (1971-2008)**




Source: SAGPyA (2009).

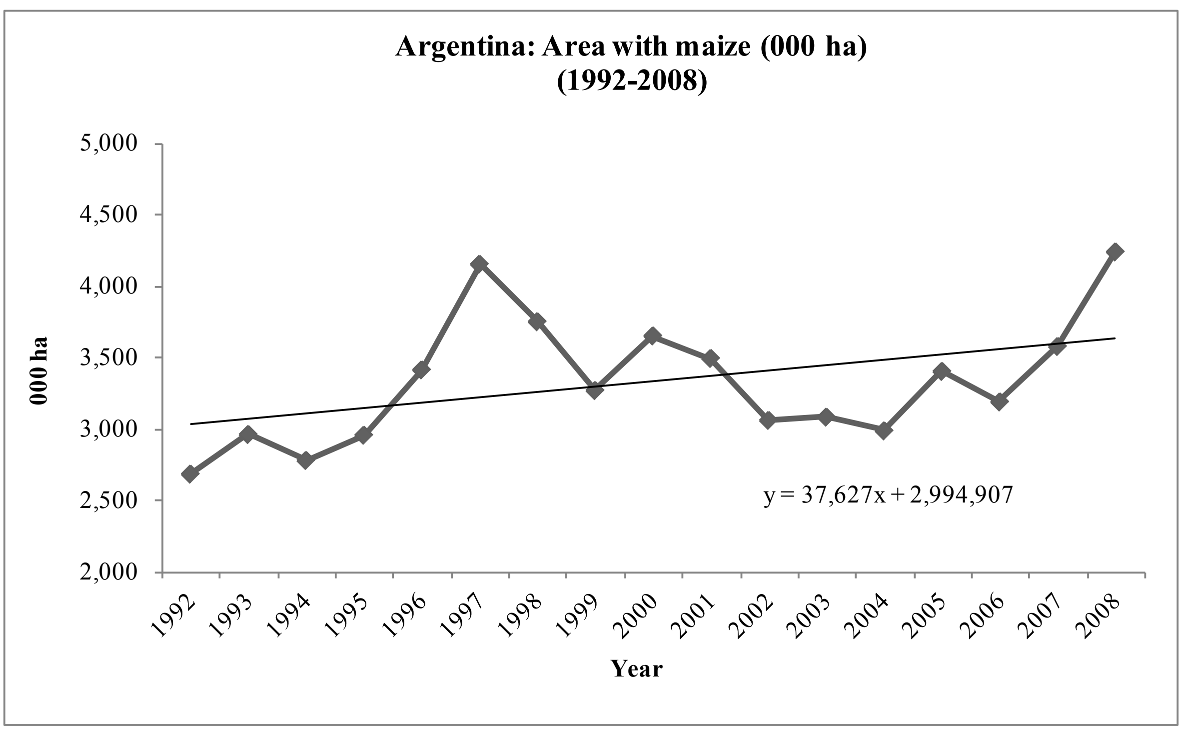
The trend for maize for the period 1971–91 was clearly downward, at a rate of about 88 thousand ha/year (see Figure A6). In 1992, however, there was a significant break in trend, turning upward at a rate of 38 thousand ha/year, considering the rest of the period under study (see Figure A7). The date 1992 coincides with the time when the area under zero-till became substantial, at 300 thousand. It appears reasonable, therefore, to link this change with the new technology. The additional supply generated by this expanded area is assumed to represent a benefit to the suppliers (farmers and others in the value chain) resulting from the availability and adoption of zero-till practices.

**Figure A6. Argentina: Area with maize (1971-1991)**




Source: SAGPyA 2009.

**Figure A7. Argentina: Area with maize (1992-2008)**




Source: SAGPyA 2009.

## The Estimation of Benefits to Consumers

Supply price-elasticity is a parameter that quantifies the $\Delta Q/\Delta p$ relationship. The elasticity formula represents the expected change in the volume supplied by farmers ($\Delta Q$) as a fraction of a change in the price of the commodity ($\Delta p$)—as known to farmers when they make the decision to plant. For example, a supply price-elasticity of 0.7 means that, for each 1 percent change in the price, supply will respond with a change of 0.7 percent in the same direction (that is, supply goes up if the price is higher, and goes down if the price drops). The supply price elasticities of soybeans and maize are useful parameters to describe the producer's responses to changes in market signals. But we lack a corresponding formula to assess the changes in quantities and quality of the basket of food items purchased at the household level, as an effect of a supply shock for specific agricultural commodities. It is true that such demand functions and parameters are routinely estimated for poultry, pork, beef, and other animal products; nevertheless, for the consumer household demand price elasticities of soybeans and maize, taken as pure commodities, such an approach is simply not feasible.

The inverse of the elasticity ratio—that is, $\Delta p/\Delta Q$—is called flexibility, and it measures the response of the price to changes in the volume supplied. Econometricians warn, however, about the error of taking the estimated value of elasticity, reversing it, and working with the resulting number as if it were an accurate estimation of flexibility. With this caveat, we decided to use, for soybeans, the inverse of an estimation of its supply price-elasticity for the United States, the world's biggest producer. That figure has been estimated at 0.80 (with other estimates ranging from 0.22 to 0.92). If we assume our figure represents the real value of the parameter instead of an estimation, its inverse (1.25) could be considered as the real price-flexibility ratio. If our assumption holds, we can estimate the effect on the world price of soybeans of the additional supply originating in Argentina, attributable to the expansion of area planted induced by the adoption of zero-till practices.

For maize, we assumed that its supply price-elasticity stands at 0.6 and that the inverse (1.67) represents an accurate estimation of its price flexibility.

Price flexibility of supply of these feed grains was thus considered the best available parameter to assess, in an indirect manner, the impact of the supply shock that took place in Argentina. That impact includes not only the impact on the "world price" of the commodity but also, indirectly, on prices of any consumer products that include those commodities (either as a component or as an input along the value chain), valued at the observed world price.

The estimates of the impact on consumers of the supply shock of soybeans and maize are presented in Tables A1 and A2 respectively.

**Table A1. Argentina: Soybeans impact on prices of supply shock from zero-till**

| Year | Soybeans World Total Production * (T) | Additional Supply Zero-Till Soybeans Argentina (T) | World Price ** (Usd/T) | Impact On World Price (%) | Δ Consumer Expenditures (M Usd) |
|---|---|---|---|---|---|
| 1991 | 103,313,555 | 144,524 | 214 | -0.17% | **-39** |
| 1992 | 114,454,684 | 291,140 | 212 | -0.32% | **-77** |
| 1993 | 115,157,925 | 411,444 | 227 | -0.45% | **-117** |
| 1994 | 136,466,904 | 518,032 | 234 | -0.47% | **-151** |
| 1995 | 126,985,270 | 649,437 | 232 | -0.64% | **-188** |
| 1996 | 130,216,631 | 802,376 | 285 | -0.77% | **-286** |
| 1997 | 144,419,660 | 765,393 | 297 | -0.66% | **-284** |
| 1998 | 160,105,220 | 1,368,971 | 222 | -1.07% | **-380** |
| 1999 | 157,806,336 | 1,397,905 | 175 | -1.11% | **-306** |
| 2000 | 161,409,973 | 1,480,945 | 187 | -1.15% | **-347** |
| 2001 | 177,925,727 | 1,806,145 | 172 | -1.27% | **-387** |
| 2002 | 181,913,593 | 2,005,193 | 198 | -1.38% | **-496** |
| 2003 | 190,766,963 | 2,315,213 | 238 | -1.52% | **-690** |
| 2004 | 205,483,881 | 1,963,270 | 268 | -1.19% | **-658** |
| 2005 | 214,244,613 | 2,600,198 | 231 | -1.52% | **-750** |
| 2006 | 222,403,973 | 2,723,289 | 234 | -1.53% | **-796** |
| 2007 | 216,144,262 | 3,208,724 | 318 | -1.86% | **-1,275** |
| 2008 | 220,840,000 | 3,227,449 | 456 | -1.83% | **-1,841** |
| 1991–2008 | | | | | **-9,069** |

Source: By the authors, based on FAO 2009, USDA 2009, and SAGPyA 2009.
* FAOSTAT; USDA 2009.
** FOB prices, Argentine Ports. SAGPyA 2009.

**Table A2. Argentina: Maize impact on prices of supply shock from zero-till**

| Year | Maize World Total Production * (T) | Additional Supply Zero-Till Maize Argentina (T) | World Price ** (Usd/T) | Impact On World Price (%) | Δ Consumer Expenditures (M Usd) |
|---|---|---|---|---|---|
| 1991 | 494,382,299 | 152,179 | 107 | -0.05 | **-27** |
| 1992 | 533,586,136 | 340,425 | 106 | -0.11 | **-60** |
| 1993 | 476,769,833 | 491,614 | 111 | -0.17 | **-91** |
| 1994 | 568,621,643 | 637,725 | 113 | -0.19 | **-120** |
| 1995 | 517,326,996 | 850,798 | 126 | -0.27 | **-179** |
| 1996 | 589,457,456 | 912,014 | 163 | -0.26 | **-247** |
| 1997 | 586,066,202 | 1,199,931 | 115 | -0.34 | **-230** |
| 1998 | 615,190,988 | 1,829,562 | 104 | -0.50 | **-317** |
| 1999 | 607,946,092 | 1,818,571 | 95 | -0.50 | **-288** |
| 2000 | 592,519,009 | 2,044,234 | 87 | -0.58 | **-296** |
| 2001 | 615,335,892 | 2,257,929 | 87 | -0.61 | **-329** |
| 2002 | 603,043,200 | 2,744,841 | 99 | -0.76 | **-451** |
| 2003 | 644,885,428 | 3,168,101 | 103 | -0.82 | **-542** |
| 2004 | 728,076,771 | 3,367,724 | 105 | -0.77 | **-591** |
| 2005 | 715,813,543 | 4,153,308 | 91 | -0.97 | **-632** |
| 2006 | 699,285,375 | 3,553,775 | 126 | -0.85 | **-744** |
| 2007 | 784,786,580 | 4,903,334 | 160 | -1.04 | **-1,311** |
| 2008 | 790,910,000 | 4,370,187 | 205 | -0.92 | **-1,496** |
| 1991–2008 | | | | | **-7,954** |

Source: Cap 2009.
* FAOSTAT; USDA 2009.
** FOB prices, Argentine Ports. SAGPyA 2009.

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