Rust, Resistance, Run Down Soils, and Rising Costs – Problems Facing Soybean Producers in Argentina

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Many university and government scientists provided critical data and insights as this report evolved. Their contributions were offered and accepted anomalously in the hope that the exchange of scientific information can continue without individuals' facing professional criticism and personal recrimination.

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Karen Benbrook helped compile the databases necessary to complete this project. She also designed the report layout and produced the final version.

I appreciate the many helpful comments provided by the team of experts asked to peer review earlier drafts of the report. They pointed to more recent and better sources of data that made it possible to sharpen this report's estimates of the impacts of changes in soybean production, including emerging challenges. I remain responsible for the analytical design, findings, and conclusions, and recognize that many uncertain factors may arise and alter the future trajectory and performance of the soybean industry in Argentina.

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This report is dedicated to the farmers, agronomists and agricultural engineers, industry leaders, and scientists who will be called upon to collectively solve the problems facing Argentina's soybean industry. My hope is that this report will help build recognition that the problems facing soybean farmers in Argentina are pressing, consequential, and warrant a well-funded and systematic campaign to identify and implement sound and sustainable solutions.

Charles Benbrook
January 10, 2005

A. Executive Summary

The phenomenal growth of the soybean industry in Argentina over the last decade has been heralded as the one bright spot in a nation suffering from international debt, rising unemployment and poverty, and a host of other economic and social problems. The combination of two technologies – no-till planting systems and Roundup Ready (RR) soybeans – has made possible one of the most rapid and dramatic transformations ever achieved in a nation's agricultural sector.

But excessive reliance on a single agricultural technology, like RR soybeans and glyphosate herbicide, can set the stage for pest and environmental problems, as well as create a dangerous degree of vulnerability to sharp downward price swings in global commodity markets. In the absence of timely changes in management systems, these problems can erode the performance and profitability of once highly-effective production systems. The early signs of major trouble are now apparent in Argentina.

The response of the nation's farmers, the grain trade, government, and agricultural researchers and engineers will determine whether problems are recognized, understood, and properly responded to, stabilizing production and profit margins. Much rides on the outcome, given the country's heavy dependence on the foreign exchange generated by exports of soybean-based products.

In the United States, insects and plant diseases rarely damage soybean plants enough to justify an insecticide or fungicide application.[1] In Argentina, a number of insects have recently emerged that cause sufficient damage to soybeans in some regions, in some years, to require insecticide applications. Plus, insecticide seed treatments are increasingly common in some production regions and are needed as a consequence of the repeated use of no-till planting systems.[2] Soybean plant diseases and fungal infections are more often a problem than insects, especially in cool, wet years.

Weeds are an entirely different story. Farmers everywhere must aggressively manage the day-to-day competition between soybeans and weeds for sunlight, water, and soil nutrients on virtually every hectare they plant, every year.

Excessive reliance on a single agricultural technology, like RR soybeans, sets the stage for pest and environmental problems that can erode system performance and profitability.

There are effective non-chemical options for managing weeds in soybean fields, but they entail added cultivation, more diversified rotations, much more worker skill and experience and attention to detail, and more labour, fuel, and wear and tear on machinery. Applying herbicides is much simpler, especially in conjunction with a no-till planting system, and generally does not increase costs and indeed often lowers total weed management expenditures. That's why 98%-plus of soybean farmers worldwide depends so heavily on herbicides in managing weeds.

But in the mid-1990s in the United States and Argentina, herbicide-based soybean weed management systems were struggling. Resistant weeds were compromising the efficacy of several major herbicide products. Costs were rising and efficacy was declining. The then-new herbicides on the market were effective when applied at low- or very-low doses because they were extremely potent and persistent (Benbrook, 2004). These characteristics also made them unforgiving. A little too much would trigger damage to the soybean plants and surrounding vegetation. Potentially damaging residues of herbicides sometimes carried over in the soil to the next crop season, stunting the emergence of new crops. And when farmers applied too little product per hectare, or sprayed it incorrectly or not at the right time, the result was weedy fields and lost yields.

[1] See the annual U.S. field crop pesticide use surveys for trends in insecticide and fungicide use on soybeans (National Agricultural Statistics Service (NASS), multiple years. These reports are accessible at http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/)

[2] No-till planting systems leave the soil largely undisturbed and lead to a layer of crop residue on the soil surface that provides an inviting and safe habitat for a number of insects.

Prior to the introduction of "Roundup Ready" (RR) soybeans in the mid-1990s, weed management was the soybean farmers' most difficult, costly, and consequential management challenge. A farmer's skill in managing weeds was often as important as the weather and market trends in determining per acre profits – or losses.

Roundup Ready soybean technology rapidly gained popularity among farmers in Argentina and the U.S. because the RR system was simple, flexible, and cost-effective. RR soybeans became the dominant choice in Argentina over a three-year period, 1997 through 1999. The rate of adoption rose from 19% in 1997 to 90% in 1999.[3] By 2002 some 99% of the total soybean acreage in Argentina was planted to RR soybean varieties. That year in the U.S., some 57% of soybean acres were planted to herbicide-tolerant soybeans, most of which were RR.[4]

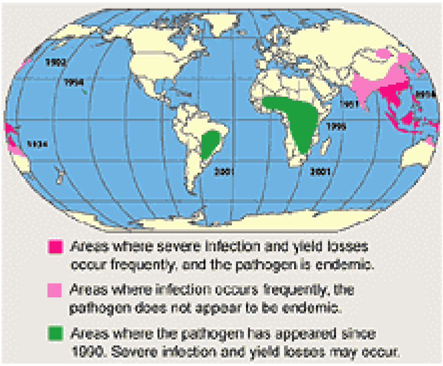
In the early 1990s, Monsanto and other seed companies were eager to gain entry to the Argentinean market. They chose not to put pressure on the Argentinean government to change seed patent and royalty payment laws. As a result, farmers in Argentina enjoyed a distinct cost-of-production competitive advantage. They gained access to RR soybean seeds without paying the approximate 35% premium for RR seed that farmers in the U.S. had to pay. Monsanto recently called for the creation of a new royalty payment system in Argentina and the company is actively involved in negogiating a draft bill (SAGPyA, 2004a).

USDA detects soybean rust in Louisiana

"The U.S. Department of Agriculture's Animal & Plant Health Inspection Service (APHIS) today confirmed the presence of soybean rust on soybean leaf samples taken from two plots associated with a Louisiana State University research farm Saturday. It is the first instance of soybean rust to be found in the U.S., but it comes at a time when most soybeans have been harvested across the country. As a result of the harvest, the impact of the fungus should be minimal this year, USDA's announcement said. APHIS officials said they believe the pathogen was carried to the U.S. during the recent hurricane season."

(Feedstuffs, 2004)

Since 1996, the year that RR soybeans were first widely planted, the acreage devoted to soybean production in Argentina has increased a remarkable 2.4-fold, from 6 million hectares to 14.2 million in 2003/2004 [SAGyA, 2004 and earlier years]. Major production regions are highlighted in Figure 1. The land needed to expand soybean production has come from five sources, as discussed in detail in section C and summarized in Table 4. The hectares planted to wheat and soybeans in the same year – often referred to as "second soy" or the wheat-soybean double cropping system – has increased about four-fold from 1996 to 2004. Since these soybean hectares are planted on land also producing wheat, they do not require the conversion of cropland formerly producing a different crop. Of the 5.6 million hectares of land newly planted to soybeans since 1996 –



Distribution of soybean rust caused by *phakopsora pachyrhizi* (Credit: APSNet)

- An estimated 25% has come from conversion of cropland growing wheat, corn, sunflowers, and sorghum.
- Other crops including rice, cotton, beans and oats account for 7%.
- Former pastures and hay fields was the source of another 27%.
- Conversion of wild lands, including forests and savannahs, account for the rest, some 41%.

[3] Throughout this report, data on the hectares planted to soybeans and other crops in Argentina are from the Secretaría de Agricultura, Ganadería, Pesca y Alimentos, SAGPYA (http://www.sagpya.mecon.gov.ar/new/0-0/agricultura/index.php); data on the hectares planted to Roundup Ready soybeans are based on ISAAA publications on the status of commercialized transgenic crops (http://www.isaaa.org/).

[4] Data in this report on the acres planted to RR soybeans and herbicide use in the United States are from annual USDA surveys carried out by the National Agricultural Statistics Service (NASS). An October 2004 report available on the Internet addresses the impacts of herbicide-tolerant crops on pesticide use in the United States. It provides a detailed accounting of the use of herbicides on RR and conventional soybeans and draws extensively on recent USDA data (Benbrook, 2004).

Given the expansion of RR soybean hectares planted, it is no surprise that glyphosate herbicide use has also risen dramatically. Total glyphosate use on soybeans increased 56-fold from 1996/97 to 2003/04 and 24% from 2002/03 to 2003/04 (CASAFE, 2004 and earlier years). The other rapidly growing use of glyphosate in recent years has been chemical fallow, another use which often is associated with the expansion of the land base planted to RR soybeans.

Reliance year after year on a single herbicide accelerates the emergence of genetically resistant weed phenotypes. Tolerance to glyphosate in certain weeds in Argentina has already been documented (Papa, 2004; Vitta et al., 2004; Puricelli, 2003; Faccini, 2000). Weeds tolerant to a herbicide like glyphosate typically become resistant over two to five years if tolerant weed populations continue to be exposed to heavy selection pressure. Given the steady increase in the intensity of glyphosate use in Argentina, the stage is clearly set for resistance to emerge. It is essentially inevitable.

Glyphosate Resistant Buckhorn Plantain *(Plantago lanceolata*)
Resistant on left, susceptible on right (Photo credit: Andrew Cairns).

The unresolved questions include which weeds will be impacted? How will farmers respond, and hence, how fast will resistant weeds spread? How will the spread of resistant weeds impact weed management costs, efficacy, and crop yields?

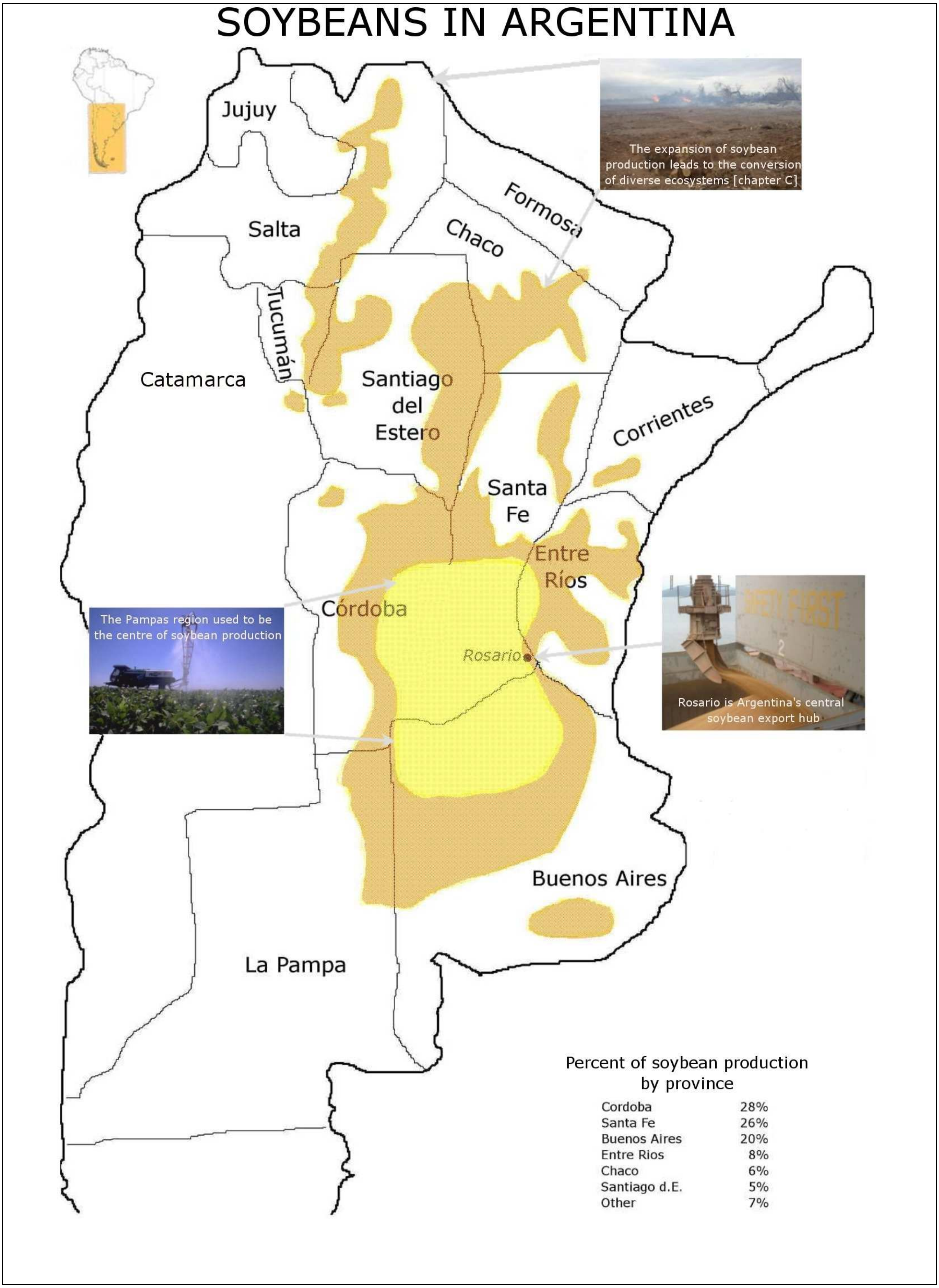
Increased reliance on herbicides is a disadvantage of no-till systems. The more farmers depend on a single herbicide, the more pronounced the ecological shifts likely to be triggered by its use. These shifts and adaptations have tangible consequences including less effective and reliable weed control, the need to spray increasingly more herbicide from year to year, higher cash expenditures, more harm to non-target organisms, and greater risk of yield losses.

The export of products made from soybeans accounted for roughly one fifth of Argentina's export earnings, a share that has grown steadily since the mid-1990s during a time when most other sectors of the economy have struggled in world markets. Soybean exports have increased some 125% since 1997 (INDEC, 2004a). At the height of Argentina's economic crisis in 2001, the government introduced a 20%-23.5% export tax (*retenciones*) on all soybean exports. Revenues from export taxes accounted for about 12.5% of total government revenue in 2003. Soybean exports are responsible for about half this important source of government tax receipts (Maino, 2003). As a result, it is little wonder why political leaders and public institutions in Argentina have grown so enthusiastic about soybeans and Roundup Ready technology.

While a record total of 70 millions metric tons of grain, half of which was soybeans, was harvested in 2002 and led to record exports in 2002-2003, almost half of the country's population still lived under the poverty line (INDEC, 2003). Revenues from export taxes were justified by and primarily meant to finance the social welfare system as Argentina worked through its economic crises, but competing priorities diverted much of these tax receipts. In 2003 only about one third was actually allocated to the national welfare plan, "Plan Jefes y Jefas de Hogar" (Head of Household Plan) (IERAL, 2004).

Soybean production has more than doubled since the introduction of Roundup Ready soybeans in 1996 and now supplies nearly a ton of beans for all 37 million Argentineans. Paradoxically though, the expansion of production has left the country less food secure. A costly set of social problems have been triggered or made worse by the adoption in farm country of capital and machinery-intensive production systems, leading to what some government officials now call 'farming without farmers.'

Figure 1. Major Soybean Production Regions in Argentina



Despite emerging pest, environmental, and social problems directly linked to the unsustainable pace of expansion of soybean production since the mid-1990s, the Argentinean agricultural sector has set a goal of 100 million metric tons of grain production by 2010, with projected soybean production of 45 million tons. Achieving this ambitious goal would require an increase of the soybean planting area to about 17 million hectares (Lopez, 2003). The major areas where the expansion has occurred to date, and will continue are highlighted in the map in Figure 1.

Little if any of this enormous increase will come from yield increases because average yields on newly cropped land will be lower as the cropland base is extended further and further away from the fertile lands and accommodating weather of the *Pampas* region in central Argentina. Even assuming steady yield increases as a result of technological change and breeding advances on the more fertile soils in the Pampas, average nationwide yields will likely remain nearly flat. Accordingly, at least 4 million more hectares will need to be planted to soybeans, a goal that will require farmers to convert cattle lands to soybeans and move further out into marginal areas, forests, and savannah regions (Cap et al., 2002; Lopez, 2003).

Hylidae – Hyline Treefrogs: *Hyla sp.* An unidentified treefrog characterized by tiny black sots on a brown dorsum. (Photo courtesy of Devon Graham, Project Amazonas, Inc.)

If the agricultural sector and government moves forward with this plan, a significant share of the wild lands left in Argentina will be altered forever at great cost to the environment, biodiversity, and the estimated 1 million of the country's population who live in and around the forests in the North of Argentina.[5] Under current government policies, the economic gains stemming from a somewhat larger share of world soybean exports will do relatively little to improve the quality of life for most people in the country.

1. Challenges Ahead for the Argentinean Soybean Industry

Soybean farmers in Argentina and the nation's economy have been enjoying the "honeymoon period" in the expansion of the soybean industry. A new generation of managers and landowners operating much larger farms, some over 60,000 hectares, have been able to vastly increase soybean production.[6] They have done it in three ways –

- Expansion onto cropland growing other crops, at the expense of Argentina's food sovereignty and security;
- Displacing poor rural people and small farmers by buying up farmland; and,
- By clearing forests.

A new-generation of farmers in Argentina have emerged that now controls extensive land holdings, including a substantial number of land owners from other countries.[7]

Argentina's new soybean operations have benefited from the relatively high natural fertility of many of the country's soils, a climate well suited for soybean production, and relatively few serious pest problems, other than weeds. But after five or 10 years in intensive soybean production, the

[5] Estimate based in INDEC (2001) National Census 2001
[6] The number of farms decreased by almost 100,000, or 21%, between 1988 and 2002, while the average acreage per farm increased from 421 to 524 hectares, or about 25% (INDEC, 2002).
[7] About 16 million hectares of land in Argentina today belongs to people from Europe, Asia, Brazil, the U.S., and other countries (La Capital, 2004).

honeymoon is coming to an end. Costs of production are rising as farmers face the need to replace soil nutrients removed with the crop each season and deal with changes in soil physical and chemical properties, especially soil compaction.[8] They are also facing new threats to crop yields as pests well adapted to life in Roundup Ready soybean fields evolve and become established. The impact of glyphosate applications of the structure of soil microbial communities and the severity of certain soil-borne pathogens is a particular concern in the U.S. and is a subject of intense research focus.

It is possible, and indeed likely that similar changes and impacts are occurring in Argentina, but no one knows for sure because the field research required to document linkages between changes in soil microbial communities and soybean plant health has not been undertaken to any significant degree in Argentina.[9]

The future competitiveness of Argentina's soybean industry will depend largely on how well farmers modify management systems to address emerging soil quality, grain quality, and pest management challenges.

This report presents clear evidence that the honeymoon period for Roundup Ready soybeans is over in both the United States and Argentina.

Successful innovation by farmers and across the soybean industry must be guided and supported in four ways –

- Reliable, region-specific research;
- Effective and continuous plant breeding programs;
- Farmer education and assistance in diagnosing problems in the field and devising and quickly implementing cost-effective solutions; and
- Adoption of policies that: (a) discourage continuation of farming methods that erode inherent production potential by, for example, exacerbating compaction and increasing the diversity of resistant weeds, and (b) support and reward farming methods that offer greater hope for sustainable yields at competitive prices.

In general, soybean producers in the U.S. enjoy significant advantages in making the changes needed as the Roundup Ready "honeymoon" draws to a close. Agricultural policies and programs are in place and well funded in the U.S. that are designed to stabilize farm income and deal with volatility in world market prices. Comparable programs are nearly non-existent in Argentina. The U.S. government is investing much more heavily in agricultural research, plant breeding, farmer education and technology transfer, and in the policy arena.

For Argentina to sustain the impressive gains it has made in the world market for soybean-based products, attention must be directed soon to emerging problems in soybean production systems and in the protein levels and quality of soybeans produced in Argentina. Evidence of quality problems in Argentinean soybeans and soybean meal was published in October 2004 in a peer-reviewed journal. A team of US scientists reported that Argentinean soybeans contained 5% to over 10% less protein than soybeans grown in the U.S., Brazil, and China, and also, levels of several amino acids were lower (Karr-Lilienthal et al., 2004). Buyers of soybean-based products from Argentina will likely seek price concessions if further research confirms the recently reported gap in protein levels.

Sustainable solutions to the soybean industry's emerging challenges are going to require substantial changes in many facets of the agricultural sector in Argentina. Reducing reliance on the herbicide

[8] Soil compaction is a physical process whereby the soil becomes tightly packed, increasing what is called "bulk density." As compaction increases, there are fewer channels in the soil where air and moisture can flow. Denser soil takes in water more slowly, thereby enhancing runoff and increasing the risk of drought stress. Root systems develop less fully in compacted soils and crop yields often suffer as a result. While not officially acknowledged as a serious problem in Argentina by government officials and agribusiness leaders, government soil scientists have documented moderate to severe compaction in many areas triggered by continuous use of no-till planting systems (e.g. Michelena et al., 2000).

[9] Personal communications with government agricultural scientists who asked to remain anonymous.

glyphosate and diversifying cropping patterns and tillage and planting systems are the most essential and immediate steps needed.

Much rides on how well Argentina works through the transition it now faces. Some farmers will be tempted to search out a pesticide for every new pest problem that emerges. Others will stick with what has worked in the past and hope that more of the same will ultimately prevail. These attitudes and reactions will set the stage for major setbacks, if not the collapse, of the Argentinean soybean industry. Attempts to mask over biological and ecological problems in soybean production systems with largely chemical-based solutions will increase pesticide use, production costs, yield variability, and environmental degradation and for these reasons, such attempts will ultimately prove too costly to sustain.

B. Growing Reliance on Soybean Production, Roundup Ready Technology, and International Trade

In both the United States and Argentina in the early 1990s, weed management was growing more costly and difficult on soybean farms using herbicide-based systems. A wide range of weed species had developed resistance to a number of widely used herbicides,[10] forcing farmers to spray one or more new herbicides that were generally more costly and trickier to use. Herbicides then new on the market were extremely active[11] and many were also persistent. They were tricky to apply because they had to be sprayed with considerable precision, and at just the right time to work cost-effectively. For some of these products, there was not much difference between an application rate that was too low to be effective and one that was high enough to damage soybean plants, or other surrounding crops and vegetation.

Herbicide spraying on a soybean field in Pergamino, Buenos Aires, Argentina.

As a result of these factors, soybean weed management costs were rising on most soybean farms, weed control was becoming more erratic, and soybean plants were periodically damaged enough by herbicides to depress yields. Solutions to these problems were proving costly and elusive.

Roundup Ready soybeans gained popularity among farmers in Argentina and the U.S. for basically the same reasons. The RR soybean system avoided the problems with low-dose chemistry and the system is simple, flexible, and cost-effective. It is also compatible with large-scale production. Farmers could apply glyphosate (the active ingredient in Roundup herbicides) at rates ranging from well less than 1.0 kilogram (kg) active ingredient per hectare to over 2.0 kg/hectare and expect at least acceptable weed control with minimal crop damage. A second application, and sometimes a third and fourth during the fallow part of the crop season, could be made if early-season applications did not work as well as needed to avoid yield reductions and the build up of weed populations. Farmers producing Roundup Ready corn, recently approved in Argentina, will apply comparable amounts of glyphosate.

Whether small or large, soybean farmers must prepare the seedbed and plant a crop on all land in cultivation, or use the no-till planting system. Planting operations must be completed within a few weeks to achieve optimal yields. A large farmer with 10,000 hectares to plant must therefore complete necessary field operations on several hundred hectares a day. By coupling RR soybeans with no-tillage planting systems, large farmers greatly simplify the tasks and steps needed to plant a crop. In most cases, the seeds are planted in one pass through the field, and herbicide and fertilizer is applied in one or two other passes. Later in the year additional herbicide applications are made.

Conventional tillage and planting systems require three to six passes through the field to plant a crop, and one or two more passes for fertilizer and pesticide applications. A farmer with 10,000 hectares to cover using conventional tillage would therefore have to complete 40,000 to 80,000 hectares worth of field operations in about a 40 day time period – requiring 1,000 to 2,000 hectares to be covered ***every day***. Moving this fast through fields requires both large equipment and a lot of it. Moreover, the primary and secondary tillage passes[12] require powerful tractors, given that wide equipment must be used to keep on schedule. Tillage equipment that rips into and mixes the soil takes a lot of power to pull across a field. These tasks require far more tractor horsepower and diesel fuel than just pulling

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[10] For an up to date list of resistant weeds to individual herbicides in given locations around the world, see the Weed Science Society of America's herbicide resistant weeds website at http://www.weedscience.org.
[11] Herbicides that are "extremely active" work at low doses because they target critical biochemical pathways in weeds and disrupt some routine aspect of weed physiology.
[12] Primary tillage operations typically are carried out with a chisel plow, heavy disc, or a moldboard plow.

a no-till planter across the field that only disturbs shallow, narrow bands of soil where the seeds are placed. As a general rule of thumb, farmers using conventional tillage need either three to four times as many tractors, and/or much larger equipment, to cover the same ground that a no-till farmer can plant with a single midsize tractor.

As soybean production expanded, newly planted land was relatively fertile and lacked significant populations of insect and weed species and plant pathogens well suited to attack soybeans. However, this situation is bound to change after several years of no-till farming.

There are several advantages and disadvantages of no-till systems. Advantages include –

- Less disturbance of the soil surface and hence markedly lower rates of erosion on sloping cropland;
- A less powerful tractor is required to pull the planter compared to the tillage equipment needed to prepare a seed bed for a conventional planter, saving fuel and time;
- A single pass through the field is required to plant a crop, compared to three to six passes using other tillage-planting systems; and,
- More hectares can be covered quickly by a single worker, making it easier to manage large acreages.

Disadvantages of no-till planting systems include –

- Near-total reliance on herbicides for weed control;
- Markedly higher costs for herbicides and more herbicides added to the environment;
- No-till systems, especially if used exclusively over many years, increase the severity of soil compaction and trigger changes in insects and weed species[13];
- Fields can become rough, making harvest operations less efficient and harder on equipment; and
- Last, it can be more difficult to establish an even stand of plants using no-till equipment.

1. Soybean Acreage and Production, 1995 – 2004

Herbicide tolerant, Roundup Ready soybeans became the dominant choice in Argentina over a three-year period, 1997 through 1999. By 2002 some 99% of total soybean acreage was planted to RR soybean varieties (ISAAA, 2004). That year in the U.S., about three-quarters of soybean acres were planted to herbicide tolerant soybeans, most of which were RR varieties.

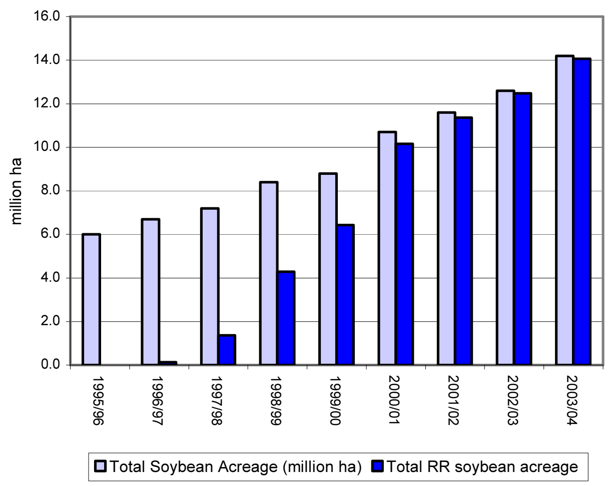
Since 1995, the acreage devoted to soybean production in Argentina has more than doubled from 6 million hectares to 14.2 million in 2003/04, as shown in Table 1 and graphically, in Figure 2. More detailed data is presented in Appendix Table 1 on the acreage planted to major crops from 1992 to 2004, shifts in acreage to soybeans from other crops, pasture and alfalfa, and forestland.

[13] Compaction triggered or made worse by no-till planting systems in the U.S. is most serious where soils have relatively high clay content, and where machinery traffic is heaviest in a field. Poorly drained soils can contribute to compaction, which in turn leads to more serious problems with water logging and uneven infiltration of rain across a field. See http://southcenters.osu.edu/soil/compact.htm for a basic overview of the factors leading to compaction and options to reverse it.

Table 1. Expansion in Soybean Acreage and Percentage Planted to Roundup Ready Varieties			
Season	**Total Soybean Acreage (million ha)**	**Total RR soybean acreage**	**Percent Roundup Ready**
1995/96	6.0	0.0	0%
1996/97	6.7	0.1	2%
1997/98	7.2	1.4	19%
1998/99	8.4	4.3	51%
1999/00	8.8	6.4	73%
2000/01	10.7	10.2	95%
2001/02	11.6	11.4	98%
2002/03	12.6	12.5	99%
2003/04	14.2	14.1	99%

Source: Total soybean hectares planted is from SAGPyA (2004), percentage of soybean hectares planted to Roundup Ready varieties is from ISAAA (2004).

Figure 2. Steady Growth in Soybean Acreage



In the history of agricultural innovation around the world, the rapid adoption of RR soybeans in Argentina is nearly without precedence. For three years running – 1997, 1998, and 1999 – just under 30% of the acreage planted to soybeans in Argentina was converted to the RR system, most of it coupled with no-till planting systems (Trigo et al., 2002). In 1997 about 1.4 million hectares of RR soybeans were planted in Argentina and in 1998, 4.3 million were planted -- a remarkable 2.9 million hectare or 200% increase in a single year!

The dramatic impact of RR soybean technology on Argentina agriculture becomes clearer when contrasting the expansion of soybean acreage in the three years prior to the introduction of RR technology (1993-1995) with the three years after its major commercial release (1997-1999). In 1993-1995, total soybean acreage increased, on average, a mere 0.23 million hectares annually, while acres planted to RR soybeans increased on average more than 2 million hectares annually from 1997-1999, or about ten-times faster.

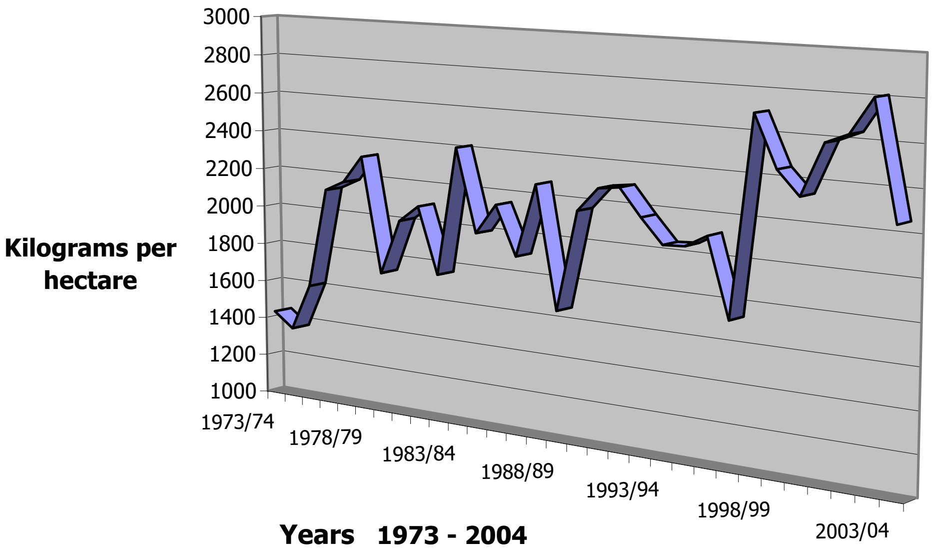
2. Yields and Crop Quality

Farmers have gradually increased average soybean yields from around 2.1 metric tons per hectare in the late 1970s to a high of 2.8 metric tons per hectare in 2003 (SAGPYA, 2004). Average trend yields have risen barely one-third over about three decades, as shown in Figure 3. Improved weed control, less soil erosion, and more timely completion of planting operations has contributed to higher yields. However, the expansion of soybean production onto more marginal lands has no doubt reduced average yields somewhat.[14] Across the whole soybean industry over the last decade, the factors increasing yields had a greater effect than the factors reducing yields, resulting in slow and steady growth in average yields.

During a December 2002 workshop in Buenos Aires on the impacts of soybean expansion on Argentina's farm sector and economy, a major soybean producer[15] reported that he harvested consistently higher yields on his farms where conventional soybeans were planted, compared to fields planted to RR soybeans under comparably favourable conditions. Still, he strongly preferred RR soybeans because of compatibility with no-till systems, the ease of field operations, and the simplicity of weed management.

[14] The average soybean yield across the country was at 2.8 t/ha in 2002/03; while it reached 3.1 t/ha in Santa Fe and 2.9 t/ha in Buenos Aires, average yields only reached 2.1 t/ha in Chaco, 2.2 t/ha in Tucuman and 2.5 t/ha in Salta (SAGPyA, 2004).
[15] Presentation by Gustavo Grobocopatel at the workshop "Transgenics in Argentine Agriculture: Toward Defining a National Policy" held December 5, 2002. Workshop sponsored by the International Institute for Sustainable Development (IISD) and the Institute for Interamerican Cooperation in Agriculture (IICA). Currently, Mr. Grobocopatel is producing approximately on 80,000 hectares annually in Argentina (and another 12,000 in Uruguay), with a turnover of 100 million dollars a year. It is likely that his operation is among the biggest, if not the biggest, soybean farm conglomerate controlled by a single family in the world.

Figure 3. Soybean Yields in Argentina, 1973 - 2004



Source: SAGPYA, 2004.

The U.S. Experience with RR Soybean Yields

The yield performance of Roundup Ready soybeans has been closely monitored in the United States. In the first few years of commercial use, there was clear evidence that most RR soybean cultivars were producing 5 percent to 10 percent fewer bushels[16] per hectare in contrast to otherwise identical varieties grown under comparable field conditions (Elmore et al., 2001; Benbrook, 1999). In recent years this kind of genetic yield drag has been reduced somewhat, in part because the Roundup tolerant trait has been moved into a broader diversity of better performing varieties. But other biological and physiological problems have emerged that also sometimes depress yields (for more, see the section on *Changes in Soil Microbial Communities* below).[17] In addition, the quality of weed control has slipped in areas where weed shifts and/or resistance or tolerance to glyphosate have emerged as significant problems.

RR varieties produced about 6 percent lower yields on average, compared to otherwise similar varieties when grown under comparable conditions, according to a team of scientists at the University of Nebraska (Elmore et al., 2001). *Farm Journal* magazine published the results of independent soybean yield trials in three states conducted under conditions designed to match those on commercial farms (Horstmeier, 2001). In Indiana, the top RR variety sold by three seed companies yielded, on average, 15.5 percent fewer bushels than the top conventional variety sold by the same companies. In Iowa trials, the RR yield drag was just under 19 percent across 17 companies, whereas a much smaller difference was observed in some other states.

Biological and physiological problems in RR soybean fields have emerged that sometimes depress yields. In addition, the quality of weed control has slipped as a result of weed shifts and resistance.

The inconsistency of the differences in yields observed across many studies suggests that a variety of factors can and do impact the magnitude of the RR soybean yield drag. In general, under ideal conditions where no plant nutrients are lacking and weed pressure is light to moderate, the yield drag is likely just a few bushels per

[16] One bushel of soybeans weighs 0.027 metric tons. One metric ton of soybeans contains 33.3 bushels.
[17] See multiple scientific articles posted under the "Herbicide Tolerant" crop section on Ag BioTech InfoNet at http://www.biotech-info.net/herbicide-tolerance.html#soy

hectare. The greater the stress on soybean plants from a lack of nutrients or nutrient imbalances, drought, or disease pressure, the larger the likely yield drag when comparing the performance of RR soybeans to conventional varieties.

In the summer of 2004 both scientists and farmers in the U.S. began expressing new concerns over the impact of the genetic modification of soybeans on average yields. A presentation by two university scientists at the "Midwest Soybean Conference" in Des Moines, Iowa on August 7, 2004 was widely covered by the farm press and has triggered an ongoing assessment of the impact of RR technology on soybean yields. The presentation was entitled "Stagnating National Bean Yields (?)" and reported that national soybean yields had risen steadily and reliably from 1972 through 1993 (Eliason and Jones, 2004). Over this period, yield growth averaged about 0.45 bushels per acre per year, but since 1995, yields have stagnated. Yield growth has been essentially zero.

The scientists estimated the potential impact of this loss in soybean productivity growth at 4.05 bushels per acre from 1995 to 2003 (0.45 bushels per acre per year multiplied by nine years). At an average price of $5.00 per bushel, the 630 million bushels not harvested cost the U.S. soybean industry $1.28 billion U.S. (Eliason and Jones, 2004). Many factors no doubt have contributed to recent poor performance in soybean yields, in addition to RR technology. But another finding reported by the scientists reinforces their conclusion that something about the RR system is depressing soybean yields. During the period that soybean yields stagnated, corn yields kept rising at an annual average rate of 1.62%, compared to a rate of growth of 1.56% from 1972 to 1993. A bumper crop of both corn and soybeans is expected in the U.S. in 2004, which will allay some of the concerns expressed in recent months regarding the stagnation of soybean yields. Still, there is evidence that soybean yield variability has increased in the U.S. Many scientists expect, but cannot yet prove that RR soybeans are more vulnerable to a range of diseases, especially when climatic, soil, and other conditions place plants under stress.

Crop Quality

The genetic modification required to make soybeans "Roundup Ready" targets a key biochemical pathway in plants that plays a central role in plant defence responses. It appears that this transformation has increased the vulnerability of the soybean plant to certain soil-borne plant pathogens, at least under some environmental conditions. Recent research also suggests that RR soybeans produced in Argentina are of inferior nutritional quality (Karr-Lilienthal et al., 2004). A team of U.S. scientists compared the protein content and quality of Argentinean soybeans and soybean meal from five countries including Brazil, the U.S., China, and India. Consistently, Argentinean soybean products contained the lowest level of crude protein. Soybeans from Argentina contained 32.6% crude protein on a dry matter basis, compared to 39.3% in Brazil, 37.1% in U.S. beans, and 44.9% in Chinese soybeans. The crude protein level in Argentinean soybeans would have to be increased 20% to match the level in Brazilian soybeans, and 38% to equal the level in Chinese soybeans, the most protein-dense soybeans tested. These are remarkably sizable differences that will impact the kilograms of gain in livestock and poultry fed soybean-based livestock feed supplements from Argentina in contrast to other countries.


Soybean seeds mature and dry in pods.

Levels of several key amino acids in Argentina's soy products were also substantially lower than those from the four other countries (Karr-Lilienthal et al., 2004). Given that essentially all the soybeans grown in Argentina were from Roundup Ready seed, whereas RR soybeans account for a portion to very little or none of the soybeans grown in the other countries, it is likely that the differences in protein levels observed arose in part because of the genetic transformation required to make soybean plants RR.

3. Seed Industry Impacts and Issues

Soybeans are largely self-pollinated plants. In contrast to hybrid seeds, farmers are able to save seeds from their fields for replanting with little or no loss of yields, a practice often referred to as the "brown bagging" of seed. When Monsanto introduced Roundup Ready soybeans in the U.S., it required farmers to pay a premium for RR seeds and sign a "technology agreement" that included a pledge to not keep harvested soybeans for replanting or sale to another farmer. The company has aggressively enforced this provision. It has prosecuted many farmers over the last decade and has even pushed the courts to impose jail terms on some farmers.[18]

Because of differences in patent and seed variety protection laws in Argentina and the U.S., few Argentina soybean farmers have paid a premium for RR soybean seed and the saving and replanting of seed is legally practiced. Many farmers also illegally sell RR soybean seed in what is called "bolsa blanca," or white bags. In addition, substantial volumes of RR seed have moved from Argentina to Brazil through illegal smuggling. According to the U.S. Embassy –

> "Currently the Argentine seed industry supplies only 20 percent (2.8 million hectares) of the seed for the total 12.5 million-hectare soybean market. On-farm seed production, which until now is considered a legal practice only if used by the farmer who produced the seed, accounts for another 20 percent of the total acreage. The remaining 60 percent of acreage is planted with illegally traded brown bag seed."
>
> (USDA, 2003)

Mature and dry soybean seed ready for harvest. (Photo by Scott Bauer, courtesy of USDA, ARS Photo Lab)

To combat the loss of revenues in Argentina, Monsanto announced in January 2004 that it was suspending seed sales and research in the country, until the government guaranteed a "fair return" for seed producers. The step is widely seen in Argentina as a means to pressure the government to enact and enforce more restrictive seed laws that will allow seed producers to penalize and prosecute farmers who save their own seed, just as U.S. farmers are now penalized. When Monsanto was lobbying for approval of Roundup Ready soybean technology in Argentina, it was well aware that current law and regulations in Argentina allowed farmers to save seed and would make it difficult for the company to collect a royalty or technology fee premium on more than a small portion of the soybean seed planted in a given year.

Three seed companies now control most of the soybean seed market in Argentina -- Nidera Handelscompagnie B.V. of the Netherlands, and two Argentinean companies, Asociados Don Mario and Relmo. These companies are required to pay royalties to Monsanto for access to their Roundup Ready technology, but remain at a competitive disadvantage in the marketplace because of the widespread availability of "white bag" seed (Smith, 2004).

[18] Examples of farmers sued by Monsanto can be found at http://www.cropchoice.com

In August 2004, Monsanto broadened its efforts seeking to justify and collect royalties in Argentina. Advertisements were placed in the country's newspapers that called for the creation of a new royalty payment system that would collect a flat fee of US$3 to US$7 per metric ton of exports of soy-based products. While the government initially rejected this proposal, the Agriculture Secretariat is currently drafting a bill that would impose fees on Roundup Ready "white bag" seeds. Monsanto is actively negotiating with the Secretariat in the hope of finalizing the draft bill before the end of 2004 (SAGPyA, 2004a). Now that RR soybeans are planted on over 14 million hectares in Argentina, the new rolyalty system would generate sizable returns to Monsanto and erode a share of Argentina's competitive advantage in the world soybean market.

4. Economic Impacts

During the economic crisis that gripped Argentina in the mid- and late 1990s, the soybean industry was one of the few economic bright spots. Export prices were stable or rising during most of the period, as shown in Figure 4 below, and brought stable U.S. or EU currencies into the economy during a period when the Peso was depreciated 70%. The U.S. Embassy in Argentina sent a vivid description of the situation in late 2002 to Washington D.C., during a period when the country was on the brink of economic collapse:

"At the annual 'No-Till' conference held recently in the cereals and oilseed trading centre of Rosario (at which attendees had the option of paying the $US 300 registration fee in grain), producers and agribusiness representatives voiced significant consensus and gave anecdotal evidence that the agriculture sector is doing well, at least for the moment. When asked about the net gain or loss to producers taking into account the stronger dollar (appreciation of 250%), export taxes on grain and oilseeds of 20-23%, inflation to date of 38%, and higher costs for diesel and other inputs, the net result was that farmers were receiving 'nearly 200%' more pesos than from the year before."

(USDA, 2002)

Ironically, throughout the country soybeans were used as a second currency and were regarded as a safer investment than many stocks or government bonds.

Over 90% of the soybeans grown in Argentina are exported to world markets for animal protein feed supplements and vegetable oil. Argentina is the world's leading exporter of soybean oil and soybean meals (USDA, 2004a). Two years after the depreciation of the peso, debate continues in Argentina over the dependency of the economy and the government's budget on soybean exports. The country's economic vulnerability is made worse by the volatility in world soybean market prices and the ongoing re-alignment of the peso to the U.S. dollar (Global Agro SA, 2003). The linking of the currencies is advantageous for exporters and the government but not for the people's buying power.

The export of products made from soybeans accounted for an estimated 25% of Argentina's exports in 2003, a share that has grown steadily since the mid-1990s during a time when most other sectors of the economy have struggled in world markets (INDEC, 2004a). An important factor leading to rising exports was the increased demand for vegetable protein supplements on the world market in the wake of concerns over mad cow disease, which dramatically limited the use of rendered animal byproducts in the production of livestock feed supplements. Given that since 1997 soybean exports have increased some 125%, it is little wonder why political leaders and public institutions in Argentina have grown so enthusiastic about Roundup Ready technology. During the height of the economic crisis in 2001, the government introduced a 20%-23.5% export tax (*retenciones)* on all soybean products shipped abroad. From 2002 to 2003, revenues from export taxes - about half of which come from soybean products – increased by 83.4% and accounted for some 12.5 % of total government revenues in 2003 (MECON, 2004).[19]

The revenues from export taxes were primarily meant to finance the social welfare system during and after the economic crisis. While income from export taxes reached some 9.2 billion Pesos in 2003, only about 3.5 billion Pesos (US$ 1.2 billion), or one third, were allocated to the national welfare plan, "Plan Jefes y Jefas de Hogar" (Heads of Household Plan). This plan offers about US$ 50 per month to households in need (IERAL, 2004).[20] Despite a record total grain harvest of 70 millions metric tons in 2002 (half of which was soybeans) and record exports in 2002 and 2003, almost half of the population still lived below the poverty line (FIAN, EED, 2003). Today, approximately 1.7 million people are officially receiving support under the Heads of Household Plan (Clarin, 2004). It can be assumed that many of these people used to work in the rural sector before (see the section *Hunger in the Land of Plenty* below).

Soybean production in the 2003/04 season reached 14.2 million hectares planted and 32 million metric tons harvested (SAGPyA, 2004). This represents more than a tripling of soybean industry output since the early 1990s and helps place into perspective the enormous likely consequences following a serious effort to attain the government's 100 million metric ton production target for all grains in 2010 (Lopez, 2003).

About three quarters of the soybeans harvested in Argentina are crushed in the country and exported as soybean oil and meal. The export of these commodities helped Argentina access animal protein feed markets in the European Union, which expanded markedly in the wake of the mad cow crisis and the banning of animal feed protein supplements made from bone meal, blood meal, and rendered animal waste products. The soybean oil market in Asia was also rapidly growing in step with the region's livestock production capacity. The biggest vegetable oil production center in the world is located in the outskirts of Rosario, Argentina's central soybean hub. Daily processing capacity in Rosario is estimated at about 70,000 tons per day (CIARA, 2003). The volume of soybeans moving into these facilities now routinely exceeds capacity. While this has fueled a major flow of investment capital into the sector and the prospects for bigger export tax revenues in the future, the business is very concentrated and relatively few Argentineans are benefiting economically. Just five companies (Cargill, Toepfer, La Plata Cereal, ADM and Dreyfus) accounted for about 75% of the total soybean exports in 2003; four companies (Bunge, Cargill, A.G.D., Dreyfus) were responsible for 70% of the total exports of soybean pellets and soybean oil in 2003 (SAGPyA, 2004b).

Investments around $535 million U.S. in 2004 by the leading companies, including Cargill, Bunge, Terminal 6, Molinos Rio de La Plata, Vicentin, AGD and Arcor (together with Grobocopatel) (CREA, 2004) will increase total crushing capacity in Argentina to 130.7 tons a day by 2006, an increase of 32%. Additional investments are planned or underway by other transnational corporations including, Dreyfus and Nidera. The Rosario stock exchange has projected that soybean production would reach 50 million tons in 2011 (Longoni, 2004).

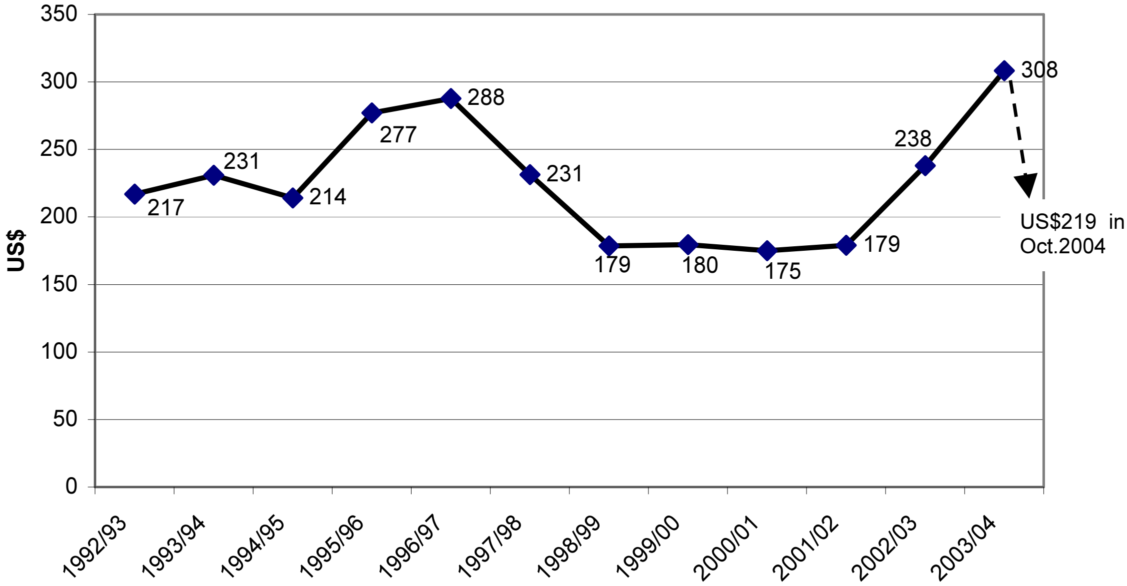
5. International Competitiveness, Trade, and Policy Trends

The global soybean market is inherently volatile. Market prices are highly responsive to shifts in carryover stock levels and the balance of supply and demand. As the data on 2003/04 in Figure 4 shows, world soybean prices can change quickly and have recently plummeted as a result of the bumper crop harvested in the U.S. in the fall of 2004.

Every time the soybean price goes down, the country feels the impact. By mid October 2004, a quarter of that year's harvest was not sold, largely because of lax demand and the decrease in world market prices (Persoglia, 2004).

[19] Some of the companies were faced with allegations for tax evasion. As a consequence, the government recently implemented a stronger law in an attempt to better control commodity export tax collections (Longoni, 2004a).
[20] The cost for the Basic Needs Basket is currently US$250 per household (INDEC, 2004b)

Figure 4. Soybean Price per Ton in US$ [FOB Buenos Aires]



Source: USDA, 2004b; SAGPyA, 2004c

The future scale and economic performance of Argentina's soybean industry will be determined by the interactions of six dominant forces shaping the global industry –

- The balance of global supply and demand for protein-based feed products;
- Access to markets;
- The peso / dollar exchange rate;
- Reform of U.S. and EU farm policies;
- Investments in infrastructure; and
- Competitiveness in terms of costs of production.

The main destinations for soybeans produced in Argentina are China, the EU and Thailand. For soybean meal, major buyers include the EU, Egypt, Malaysia and Thailand, with the EU being the world's largest importer of soybean meal, accounting for almost 50 percent of global trade (SAGPYA, 2004; Reca, 2001). Argentina's soybeans and meal have moved into European Union markets for over a decade with few impediments, despite the public concern over genetically modified foods. This is primarily because the vast majority of the soybeans from Argentina are destined for the animal feed market, where farmers and agribusiness are the major customers. Since May 2004, genetically modified (GM) animal feed has fallen under EU labelling regulations, but consumers are generally unaware of these labels. At this time, the meat, poultry, and dairy products that people buy in stores do not have to be labelled if they were fed GM feed.

Estimates for the additional costs of implementing a traceability and segregation system in Argentina for soybeans are $14 per ton plus investments of $40 million per 1 million tons of soybean crushing capacity (SAGPyA/FAO, 2004). Research cited in Trigo *et al.* concluded that the price difference between GM and non-modified soybeans was not large enough in the late 1990s to justify the expense in implementing an identity preservation system in Argentina. Given that virtually all soybeans grown in Argentina are Roundup Ready, these cost estimates are meaningless. Labelling is inexpensive in countries like Argentina where essentially all soybeans are genetically modified.

Soybean exports from Argentina destined for Europe will have to be labelled as produced from GM soybean seeds. Some supermarkets and food companies in the EU are likely to require certification from their suppliers of animal products that livestock were not fed GM soy-based protein. To avoid the possible loss of markets, some livestock producers and animal feed manufacturers will likely seek out sources of conventional soybeans and soybean products from wherever they are available. Many other markets, however, are likely to remain open to Argentinean GM soybean products, unless new evidence emerges questioning the safety or nutritional quality of RR soybeans.[21] In early 2006, the EU permit for RR soybeans will expire, triggering a new review and approval process. If approval is delayed or denied, this would have major impacts on the global soybean market.

Possible Labeling Terminology

- Contains no genetically engineered ingredients
- Certified organic
- Certified organic corn and soy meal
- Certified organic corn and soy oil
- No genetically engineered ingredient is present in this product
- Less than 5% of the ingredients (by weight) is genetically engineered
- Our suppliers guarantee they do not plant genetically engineered seeds.
- All natural ingredients
- GM-free

(Center for Food Safety and Applied Nutrition, FDA)

The science required to definitively establish the equivalency of the safety and nutritional quality of RR soybeans has not been done. The food quality and risk assessment science supporting judgements of "substantial equivalence" between RR soybeans and conventional varieties has been both shallow and limited, and under the best of circumstances, would only detect profound differences. Much more work is clearly needed and important new lines of research are underway.

The current high degree of vulnerability of the Argentinean economy on the world's willingness to accept GM soybeans is clearly an issue the government should take into account in devising long-range policies for the agricultural sector. Brazil, as the second largest soy exporter, will continue to play a major role in shaping the global market and establishing the terms of trade. If Brazil continues its efforts to preserve GM-free status for at least some major production regions, exports from Brazil may come to be viewed preferentially by importers seeking out non-GMO feedstuffs. Such a policy could lead to a division of the global soybean meal and oil market according to GM status and country of origin.

Competitiveness

In the early years of adoption of Roundup Ready soybeans in Argentina, it was crystal clear that lower prices for seed and glyphosate herbicide enhanced the competitiveness of the Argentinean industry compared to the U.S. and other major producers. Many analysts have suggested that costs in Argentina were about 25% lower than in the U.S. (Qaim and Traxler, 2004; Trigo et al., 2002). It is equally clear that a number of factors are chipping away at the magnitude of these advantages and that Argentina's costs are now rising faster than costs in the U.S. This is another sign that the honeymoon period of Roundup Ready soybeans is coming to an end in Argentina.

[21] Such evidence has recently emerged (Karr-Lilienthal et al., 2004) and is discussed in the "Crop Quality" section (see B.2). The new data showing that Argentina soybeans and meal have less protein than soybean-based products grown in other major exporting nations is not likely to trigger import restrictions, but it may lead livestock producers to seek out higher quality products or request discounted prices for Argentina's soybean exports.

Argentinean farmers have the right to save seeds for their own use. Approximately three-quarters of the RR soybean seed planted in Argentina is "brown bag" or "white bag" seed, with between 25% and 40% sold illegally but without repercussions because of the weak enforcement of Argentina's seed laws.[22] The cost per unit of brown or white bag seed is equal to the going market price per bushel of soybeans and a small charge for seed cleaning. Farmers purchasing seed typically pay three to four times more.

In the U.S. farmers must purchase all their RR seed each year because of the provision in technology agreements prohibiting the replanting of harvested RR soybeans. In addition, RR seed costs about 35 percent more than comparable conventional seed. Accordingly, farmers in Argentina have benefited from a substantial "windfall profit" compared to farmers in the U.S. by virtue of access to RR soybeans at little or no added cost.

A second major economic factor has reduced the cost of the RR system in Argentina compared to conventional tillage and soybean varieties -- the relatively low and falling price of Roundup (glyphosate) herbicides. The price of an acre-treatment with glyphosate herbicide has declined in the U.S. from about $10.00 to $12.00 in 1996 to $7.00 to $8.00 in 2001, or by about one-third. The price of glyphosate has declined from $5.63 per liter of formulated product (48 percent glyphosate) in 1995/96 to $2.67 in 2000/01 in Argentina, over a 50 percent drop (Qaim and Traxler, 2002). Very low-cost glyphosate imported to Argentina from China accounted for about one-quarter of the volume sold in recent years and led to the filing of an anti-dumping case by Monsanto against Chinese herbicide manufacturers. While the Argentinean Ministry of Finance dismissed the case in February 2004 (China People's Daily, 2004), the case likely triggered changes in the marketing tactics used by companies importing and selling Chinese glyphosate. Glyphosate prices in Argentina actually rose in 2004 to around U.S.$ 3.30-3.50, largely as a result of a drop in low-cost imports from China (Palermo, 2004).

Loading a shipment of soybeans in an ocean freighter.

Prices for glyphosate products continue to fall in the U.S. as the number of generic manufacturers increases. Monsanto recently announced that there will be another substantial decrease in the price of its entire line of glyphosate-based herbicides in 2005, combined with enhancements in the incentives offered to farmers agreeing to purchase only Monsanto seed and herbicide products, a marketing practice called "bundling."[23]

[22] This estimate was presented by several speakers at the December 2002 workshop described in footnote 13.
23 Monsanto's aggressive use of incentive programs based on the bundling of production inputs has already attracted the attention of the antitrust marketing division of the U.S. Department of Justice.

C. Land Use Changes Accompanying Growth in Soybean Production

The introduction and popularity of Roundup Ready soybeans in Argentina has contributed to fundamental changes in land use and agricultural practices. The rapid shift of land to soybean production eroded two traditional sources of strength in the Argentinean agricultural sector – the coupling of livestock and crop production on the same farm, and second, adherence to diversified rotations, needed in order to break pest and disease cycles and sustain soil productivity.

The enormous increase of land devoted to soybean production came from reduced planting of sunflowers and other crops, conversion of pastures and forage crops to soybean production, the clearing of new cropland, and the increase in double-cropping systems involving production of a soybean and wheat crop in the same year. Until recent years, the maize-wheat-soybean rotation was followed on most of the approximately 55 million hectares of high quality cropland in the Pampas region. But in order to accommodate growth in soybean production, many farmers are now growing soybeans every year, or every other year. Worries about the consequences of monoculture were virtually unheard of in Argentina through the late 1990s but now are painfully evident and openly discussed, even by government scientists.[24] Miguel Campos, the Agriculture Secretary, was quoted as saying that "soya like this is dangerous because of the nutrient extraction… this is a cost that we are not considering when we measure the results" (Huergo, 2003).

Problems associated with a lack of diversity in crop rotations and cropping practices arise for three major reasons in Argentina. Farmers are increasingly growing a single crop, soybeans. For weed control they are applying a single herbicide, glyphosate. And third, they are relying on a single planting system, no-till. This combination of excessive reliance on single tools and tactics heightens the vulnerability of the soybean industry to a host of ecological and biological problems, some of which are already apparent.

1. Overview of Major Changes in Land Use Driven by the Expansion of Soybean Acreage

Since 1995 the area planted to soybeans has increased by 8.2 million hectares, from just over 6 million to 14.2 million hectares, as shown in Table 2. The land area devoted to soybeans grew by only 230,000 hectares annually from 1992 through 1995/96, prior to the introduction of RR soybean technology in 1996. A few years later when the expansion was in full swing, soybean acreage rose 1.9 million hectares in a single year – eight times the annual pace in the early 1990s. Complete data on the land area devoted to soybeans, other crops, pasture and forage crops, and forest conversion from 1992 through 2003/04 are provided in Appendix Table 1.

The 137% growth in the land area devoted to soybeans since 1995/96 has triggered profound changes in national land use. The expansion began in the fertile and humid Pampean regions of northern Buenos Aires, southern Santa Fe, and southwest Córdoba provinces. In these regions, moderately intensive and diversified cropping systems, dependent on rotations and well integrated with livestock production, gave way to increasingly industrialised production systems, and recently, monoculture. As a result, soil fertility began declining, triggering the need for substantial increases in fertilizer use. In 1990 in the Pampas, only some 0.3 million tons of fertilizer were applied. Some 13 years later the application of 2.3 million tons has still not reversed the steady decline in fertility. For the country to achieve its goal of 100 million tons of total grain production, an increase in current use of fertilizers to at least 4 million tons is anticipated (Oliverio et al., 2004).

The National Institute for Agricultural Technology (INTA) has called attention to the decline in soil fertility. A recent paper states "… there is a strong perception…that the process of agriculturization that can be observed in the non-pampaen areas…(which is totally attributable to the expansion of the

[24] For example, a recent article was posted on the website of INTI, the National Institute for Industrial technology entitled "Causes and risks associated with soy monoculture" (INTI, 2004). A recent paper by INTA (Argentina's federal agricultural research agency) scientists is entitled "Monoculture of Soybean and the Sustainability of Cordoban Agriculture" (Martelotto et al.)

soya monoculture) constitutes a path that is incompatible with the sustainability of the agricultural production in these regions" (INTA, 2003).

Soybeans now cover as much as 80% of the cultivated cropland in these regions, making rotations either infeasible or too short for maximum benefit. Because there is no room for expansion of soybeans without further reducing production of other crops and animal products that feed the Argentinean people, farmers have had to look elsewhere for new land to convert to soybean production. Since the late 1990s the soybean frontier has extended deeper and deeper into other areas and provinces. In 2002/03 the expansion of the agricultural border was almost completely due to soybean production. While soybeans displaced other crops on a considerable scale, an estimated three-quarters of the new agricultural land was occupied by soybeans (Maino, 2003). It has moved north, south, east and west. It has led to the draining of wetlands, attempts to farm in flood plains, the clearing of forests and savannahs, and the movement of intensive agriculture and cattle up hillsides. It is now moving steadily through the northwest provinces of Santiago del Estero and Salta, and the northeastern provinces of Chaco and Formosa. In the east, the less fertile and vulnerable soils of Entre Ríos are being converted to soybean production, with regrettably predictable consequences (erratic and generally lower yields, soil erosion, poor economic returns).

Change is coming so fast to land use and agricultural production methods in Argentina that it is difficult to predict and document the consequences. Argentina's expansion of soybean production is a modern-day equivalent of the Gold Rush that began in California in 1849. Regrettably, Argentina's embrace of the "golden bean" may prove as short-lived as California's Gold Rush.

Table 2. Changes in Acreage Devoted to Major Crops in Argentina from 1995/1996 to 2003/2004

	1995/1996	2003/2004	Change from 1995 to 2003/2004	
			Hectares	Percent
Soybeans	**6,002,155**	**14,226,000**	**8,223,845**	**137%**
Wheat	5,087,800	6,036,000	948,200	19%
White Wheat	54,800	46,600	-8,200	-15%
Sorghum	670,680	544,000	-126,680	-19%
Corn	3,414,550	2,860,000	-554,550	-16%
Sunflower	3,410,600	1,835,000	-1,575,600	-46%
Other Crops				
Rice	211,400	172,000	-39,400	-19%
Oats	1,847,915	1,344,030	-503,885	-27%
Cotton	1,009,800	265,000	-744,800	-74%
Beans	265,220	126,000	-139,220	-52%
Total, Major Land Uses	21,974,920	27,454,630	5,479,710	**25%**
Major Land Uses Not Including Soybeans	15,972,765	13,228,630	-2,744,135	**-17%**

2. Forest and Wildlands Conversion

Soybean expansion today extends into the largely natural areas of northern Argentina, including the Yungas and the Chaco forests, and results in the conversion of ecosystems rich in biodiversity to agricultural production. It also triggers the displacement of rural and forest people and the loss of their livelihoods and cultures. The exercise of political and economic power by large landowners and companies in the soybean business is often a routine part of the process, including influencing the judicial system when disputes arise over land tenure and the legitimacy of land titles. Violence is increasingly common as desperate people try to preserve their homes and homelands by stopping the advance of the machines cutting into the forest (FIAN and EED, 2003).

The export of the Pampas model of intensive, mechanized agriculture built around RR soybeans into areas with completely different soils and rainfall patterns is a process often referred to as the "pampanisation" of the North (Pengue, 2004). Lower production costs through the combination of Roundup Ready soybeans and no-till systems facilitated the expansion into marginal areas where soybeans were not produced before or were grown only in small pockets (AACREA, 2003; Begenesic, 2002). This is especially the case in Santiago del Estero, Salta and Chaco (Franco, 2004).

Soybean expansion leads to the conversion of native forests. Fire is one of the most widely used tools used in this process.

According to official government figures, the forest conversion rate in the north of Argentina is three to six times higher than the world average. Of the 2.1 million hectares converted over the past decade in the province of Salta alone, at least 75% have been devoted to soybean planting (Ministerio de Salud y Ambiente, 2004). Table 3 provides a compilation of government statistics on forest conversion across seven provinces from 1998 through 2002. It also projects forest clearing in the last two years, as well as since 1998. The estimates in the table are based on reports issued by official government departments.

Table 3. Conversion of Forest to Soybean Production in Argentina from 1998 to 2002 (see notes below)

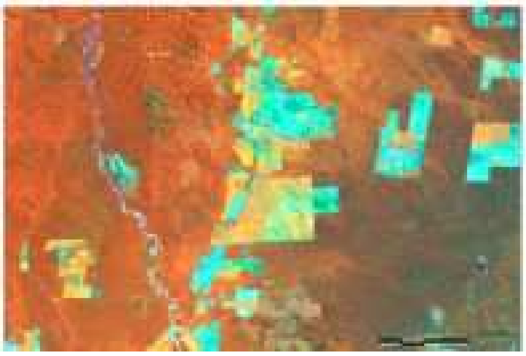
Province	Estimated Loss of Native and Fragmented Forests (Hectares converted)		
	1998-2002	2003-2004	1998-2004
Santiago del Estero	359,462	269,597	629,059
Formosa	21,550	16,163	37,713
Salta	206,003	154,502	360,505
Chaco	118,373	88,780	207,153
Córdoba	130,000	97,500	227,500
Tucumán	26,057	19,543	45,600
Entre Rios	500,000	200,000	700,000
Total for Seven Provinces	**1,361,445**	**846,084**	**2,207,529**
Average Annual Loss	**272,289**	**423,042**	**315,361**
Notes and Assumptions:			
1. The above seven provinces account for the majority of deforestation triggered by the expansion of soybean production in Argentina			
2. The land area converted in 2003 and 2004 is projected to be 75% of the area converted in 1998-2002, reflecting the substantial increase in the land area planted to soybeans in 2003 and 2004. Total growth in soybean production in 2003-2004 was about 2.5 million hectares, so forest conversion accounted for an estimated 34% of the increase in soybean cultivation.			
Sources:			
Data for 1998-2003 for Santiago del Estero, Salta, Chaco and Tucuman from the Ministerio de Salud y Ambiente – Secretaria de Ambiente y Desarrollo Sustenable, Direccion de Bosques Nativo. http://www.medioambiente.gov.ar/bosques/umsef/cartografia/default.htm			
Data for Formosa and Cordoba are based on estimates provided by experts in the region (for an account of estimates, see Rocha (2004).			
Data for Entre Rios is extrapolated from conversion figures covering 1997 through 2003 reported by UNER (2003). In this period, a total of 636,000 hectares was reported as converted.			

From 1998 through 2002, an average of 272,289 hectares were converted from forest to agricultural production each year across the seven provinces. In 2003 and 2004, the acreage planted to soybeans accelerated much more rapidly in response to rising world market prices, triggering an increase in the rate of forest conversion. An estimated 423,042 hectares were converted in both 2003 and 2004, accounting for 41.7% of the increase in the land area devoted to soybean production. Over the seven-year period covered in Table 3, an average of 315,361 hectares were converted annually. If the acreage producing soybeans continues to grow in Argentina, it is likely that at least one-third, and perhaps as much as one-half, of the new acreage will come from the conversion of forest and fragmented rural lands.

The advance of conversion deeper and deeper into forests can be clearly seen in the satellite sequence in Figure 5 below.[25] These forest ecosystems are the home of jaguars, monkeys, pumas, and more than 50% of all bird species of Argentina including tucans and parrots.

Figure 5. Rio Seco area, Salta, Northern Argentina

This grid of 60x40km in the Rio Seco area, Province of Salta, illustrates the ongoing conversion of native forests (dark areas) into agricultural land (discontiguous areas in turquoise, light green, orange) during the last years.



1989

1997

2004

[25] ProYungas Foundation. *Selva Pedemontana* satellite images March 2004.

In the flat area of the Yungas, known as "Selva Pedemontana", there are more than 100 tree species, 40 of which are endemic to this region, including ten species of high value for milled timber. Use of these forestlands to produce certified lumber would have likely provided more jobs and probably greater and more sustainable economic returns than the land will be able to sustain now that it is converted to soybean or cattle production. There has been little careful and independent economic analysis to determine the long-run consequences of major land use changes in Argentina, which are summarized in Table 4.

Major Land Use Changes

Relatively little is known about the land use changes in recent years driven by the expansion in soybean cultivation in Argentina. Other than data on the hectares planted to major crops, there are no official statistics on land use changes in 2003 and 2004 triggered by the explosive growth in soybean production in the last two years. A rough sense of land use changes can be inferred from the limited data that are available. A detailed discussion of information sources and the methods and assumptions used in projecting land use changes is presented in Appendix 1. Appendix Table 1 is the source of the data in Table 4 below.

The forest conversion rate in Northern Argentina is three to six times higher than the world average.

The first line in Table 4 shows the hectares planted to soybeans from 1996/97 through 2003/04, the period when the availability of RR soybeans and no-till greatly accelerated the expansion of soybean production. A total of just over 80 million hectares of soybeans were grown in Argentina in this eight-year period. The second line in the table is an estimate of the number of hectares of soybeans grown on land that also produced wheat in the same year, a practice known as double-cropping. There are no official statistics on the land devoted to double cropping by year, but it is widely agreed the practice was infrequently used until the mid-1990s and has risen in popularity in recent years. Overall, an estimated 15.3 million hectares of soybeans were grown in double-crop rotations with wheat in the eight-year period, which is one reason why wheat hectares planted have also risen in recent years in Argentina.

The next two lines in Table 4 estimate the hectares of land planted to soybeans (not counting double-cropped hectares) and the change in soybean hectares from the year before ("Land Newly Planted to Soybeans"). Then, the last four lines in the table estimate the portion of the new land planted to soybeans that came from the four major sources –

- Major crops like wheat, sorghum, corn, and sunflowers;
- Other crops including rice, cotton, oats and beans;
- Pasture and land growing forages for livestock; and
- Forests and land in mixed forest and/or savannah cover.

Over the eight-year period, about 25% of soybean expansion came from conversion of major crops. Other crops accounted for another 7%. The planting of soybeans in pastures and hay fields accounted for 27% of newly planted soybean hectares, and forests and savannahs accounted for the rest, some 41%.

The agricultural sector has set a goal of 100 million metric tons of grain production by 2010, with soybeans accounting for 45 million tons. Soybean production stands today at about 35 million metric tons. Average yields on newly cropped land will be lower as the cropland base is extended further and further away from the fertile lands and accommodating weather of the Pampas. Even assuming steady yield increases as a result of technological change and breeding advances on the more fertile soils in Argentina, average nationwide yields will struggle to remain flat. Accordingly, the land area planted to soybeans must be increased appreciably in order to meet the 45 million metric ton production goal. This means that at least an additional 4 million hectares of land will need to be converted to soybean production, most of it from outside the nation's major, established farming regions. The consequence of this expansion will irrevocably change a significant share of the wild lands left in Argentina and will have an enormous impact on the environment, biodiversity, and the approximate one million people who live outside the major cities and farming regions.

Table 4. Land Use Changes in Argentina Linked to the Expansion of Soybean Plantings: Estimates of Changes in Hectares from 1996 to 2004 (see notes below)

Major Land Use	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	Totals 1996 to 2003/04
Soybeans	6,669,500	7,176,250	8,400,000	8,790,500	10,644,330	11,639,240	12,606,845	14,226,000	80,172,665
Double-crop Soy Hectares Planted	650,000	800,000	1,400.000	1,600,000	2,400,000	2,700,000	2,800,000	3,000,000	15,350,000
Soybeans minus Double-crop Hectares	6,019,500	6,376,250	7,000,000	7,190,500	8,264,330	8,939,240	9,806,845	11,226,000	64,822,665
Land Newly Planted to Soybeans	467,345	356,750	623,750	190,500	1,073,830	674,910	867,605	1,419,155	5,673,845
Previous Land Use of Newly Planted Soybean Acreage									
Major Crops	140,000	80,000	150,000	70,000	300,000	200,000	240,000	350,000	1,390,000
Other Crops	60,000	20,000	60,000	10,000	80,000	30,000	40,000	120,000	400,000
Alfalfa & Pasture	107,345	36,750	133,750	29,500	353,830	224,910	341,605	349,155	1,517,845
Forest or Savannah	160,000	220,000	280,000	300,000	340,000	220,000	246,000	600,000	2,366,000

Notes: See Appendix Table 1 for more complete data, data sources, and explanation of the assumptions used in making the estimates.

D. The Impacts of Soybean Expansion on Food Sovereignty, Food Security and Nutrition

Soybean production has more than doubled in Argentina since the introduction of Roundup Ready soybeans in 1996 and now supplies nearly a ton of soybeans for all 37 million Argentineans. Paradoxically though, the expansion of soybean production has left the country less food secure. Hectares once producing essential edible crops like potatoes, beans, rice, and sorghum, as well as legume forages and pasture for beef and diary cows, have been converted to soybean production destined for export markets. In large part as a result, the share of the population facing hunger has risen sharply, as shown in the official government statistics presented in Figure 6 below for the Buenos Aires area, the nation's most heavily populated region.

According to national statistics on food production, the potato harvest fell from 3.4 million tons in 1997/98 to 2.1 million in 2001/02. Production of green peas has fallen from 35,000 tons 1997/98 to 11,200 tons in 2000/01, lentils from 9,000 tons to 1,800, dry beans from 340,000 in 1998/99 to 278,000 in 2001/02. The production of animal protein, dairy products, and eggs have also dropped significantly –

- Milk down from around 10 billion litres in 1999 to 8 billion litres in 2002.
- Eggs fell from 5.7 to 4.6 billion during the same period.
- Beef dropped from 12.8 million animals 1997 to 11.3 million in 2002.
- Pork production dropped from 214,583 tons in 1999 to 165,292 tons in 2002.
- Poultry production fell from 940,246 tons in 1999 to 699,440 tons in 2002 (MECON, 2002).

1. Hunger in the Land of Plenty

Poverty is measured in Argentina by an institution called INDEC, the Argentinean Statistics and Census Institute. INDEC uses two basic measures to monitor poverty. The "incidence of poverty" is based on the proportion of households whose income does not surpass the value of the "Basic Nutrition Basket." Any household unable to afford a "Basic Nutrition Basket" would lack adequate caloric intake and/or consume inadequate levels of certain nutrients that are needed to sustain health. The "incidence of indigence" is based on the proportion of households too poor to afford what is called a "Basic Needs Basket," which includes food, housing, and clothing.

Indigent families including young children are common in urban areas. (Photo by Celia Escudera-Espadas)

From October 1996, the beginning of the major soybean expansion, to October 2002 the number of people lacking access to a "Basic Nutrition Basket" grew from 3.7 million to a remarkable 8.7 million, or about 25% of the entire population. The latest data released by INDEC reports that 47.8% of the population were poor in the second half of 2003 (INDEC, 2004). INDEC data on poverty are displayed graphically in Figure 6 and paints a disturbing picture. While INDEC does not provide statistical information on the level of hunger and poverty in the whole of Argentina including rural areas, the figures for the urban population give an idea of the massive lack of access to food. More than 4 million children under the age of 15, almost two out of every three, lacked access to adequate food. The incidence of indigence among children under 14 years old was

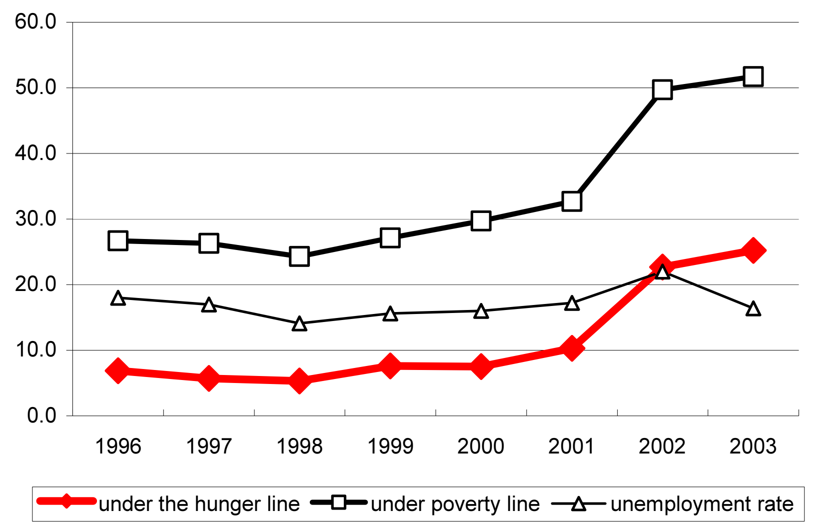
2.5 times higher than the rate among older people. Levels of poverty and indigence are higher in rural areas than in and around major cities (FIAN and EED, 2003).

The unemployment rate climbed steadily from a low-point of 5.3% in October 1991 to a peak of 22% in May 2002. It has since declined well below 20%, although rates remain disproportionably high in rural areas (FIAN and EED, 2003). The massive expansion of the soybean industry has produced a net loss of jobs since the number of small to mid-size farmers that have been displaced exceeds the number of new jobs created in the soybean production and processing sectors. Because the combination of no-till and glyphosate resistant seed makes the production of genetically engineered soybeans so simple, the Sub-secretary of Agriculture stated that for every 500 hectares incorporated into soybean agriculture in Argentina, only one new job is created on the farm (DellaTorre, 2004). Based on the average size of moderate-scale family farms in Argentina, the same 500 hectares would likely support four to five families and a half-dozen or more jobs. The Argentinean government now acknowledges that soybean industry growth has triggered social problems (Huergo, 2003) and that the tendency towards 'farming without farmers' must be reversed to promote the social sustainability of the agricultural sector (Casas, 2003).

An international fact finding mission of FIAN (Food First Information & Action Network) and EED, a development organisation affiliated with the protestant church of Germany, concluded, that "the human right to adequate food in the visited cases is being violated" (FIAN and EED, 2003).

The April 2003 FIAN report identified several reasons including: "Destruction of the existing access to a livelihood through evictions of peasant families owning land in the north-western and north-eastern provinces of Argentina," and "absence of State protection for peasant families owning land against systematic and continuous attacks of landlords, who want to seize their land". The mission accused the Argentinean government of breaking its obligations under the International Covenant on Economic, Social and Cultural Rights (ICESCR) (FIAN and EED, 2003). There is little doubt that much of the land forcibly seized from peasants by large landholders was sought after in order to expand the acreage devoted to soybean production. Growth in soybean production has come at a heavy price. Both forests and basic human rights have been swept aside in the course of making more room for the "queen of Argentinean agriculture."

Figure 6. Hunger, Poverty and Unemployment as Percentage of the Population of Gran Buenos Aires 1996 - 2003



Source: INDEC, 2004.

2. "Soja Solidaria" Fails to Improve Nutritional Status

As hunger and poverty worsened across the country, the Argentinean No Till Farmers Association, or AAPRESID,[26] launched a campaign under the name of "Soja Solidaria" in February 2002. The campaign called upon soybean farmers to donate 0.1% of that year's harvest to feed the poor, especially children (Huergo, 2002). Soybeans, however, are not part of the Argentinean diet. Accordingly, the campaign required a massive educational effort focusing on how to prepare raw soybeans into edible foods.

The Argentinean Society for the Use and Development of Soybeans, SADESO, was one of the groups coordinating the educational campaign. This group claimed that soybeans could replace milk and meat in healthy diets and reduce the incidence of malnutrition (SADESO, 2002). Teams of people began training housewives and cooks in the preparation of soybean-based dishes, a process that includes soaking and cooking or baking of the soybeans to make them more palatable. Participants were also told that soybeans would provide not only protein but also iron, calcium, zinc and many other essential nutrients. The organisers claimed that more than a million people participated in the program and the initial press coverage of the campaign was "massive" (Backwell et al., 2003).

Several nutritionists and pediatricians raised concerns about the program and noted inaccuracies in the claims made as part of the educational campaign. For example, soymilk does not contain calcium. They also noted extensive research documenting that consumption of raw or lightly processed or cooked soybeans can reduce the uptake of several vitamins and minerals and lead to excessive intakes of phytoestrogens for women and childhood. Their concerns and warnings had no apparent impact on the campaign until a UNICEF sponsored "Forum for a National Food and Nutrition Plan" was held under the auspices of the wife of then President Duhalde. The forum was held in July 2002 and respected international experts speaking on behalf of UNICEF warned that soybeans were by no means a panacea for malnutrition and should only serve as a complement to a diversified and otherwise balanced diet (Consejo Nacional de Coordinación de Políticas Sociales, 2003). While soybeans can provide valuable protein when properly prepared and consumed, soybeans are not part of the traditional Argentinean diet and people lack the knowledge and sophistication of Asians in soybean processing and food manufacturing. Soybeans and soy-based foods are also deficient in many other nutrients and can interfere with the absorption of iron and zinc. Speakers at the forum also pointed out that soymilk should not be recommended as a substitute for milk, given its lack of calcium.

Last, the scientists warned that soy consumption is not recommended for children under 5, and especially those under 2 years of age, because of the potential estrogenic effects of the isoflavones in soybeans. Experts at the forum recommended to the campaign organizers that they make donations of other foods.

Despite heavy advertising, the Soja Solidaria campaign led to the donation of only some 988 tons of soybeans. Major agribusiness firms and soybean processors and exporters provided only weak support to the campaign -- Cargill, Monsanto and Bunge provided exactly 30 tons each (Soja Solidaria, 2003). Only 58.7 tons were donated between March 2002 and November 2003 in and around Rosario, the center of the nation's soybean crushing and exporting industry (Soja Solidaria, 2003a). Total daily soybean processing capacity in this part of Argentina was about 70,000 tons per day during this period (Ciara, 2003).

[26] Argentinean No Till Farmers Association, , http://www.aapresid.org.ar/

E. Pesticide Use, Impacts, and Likely Trends

The basic purpose of Roundup Ready technology is to make it possible for farmers to rely more heavily on herbicides for weed control, and in particular, on glyphosate (Roundup) herbicide. Increased reliance on herbicides is also a disadvantage of no-till planting systems. The more farmers depend on a single herbicide, the more pronounced the ecological shifts likely to be triggered by its use. The ecological shifts and adaptations triggered by heavy use of glyphosate are not simply of academic interest. They have tangible consequences including less effective and reliable weed control, the need to spray increasingly more herbicide from year to year, higher cash expenditures, more harm to nontarget organisms, and greater risk of yield losses.

It is widely acknowledged that Roundup Ready soybeans have driven dramatic increases in the consumption of agrochemicals in Argentina. One analyst projected that around 42.6% of the total of volume of pesticides applied by farmers in Argentina in the late 1990s were used to grow RR soybeans (Pengue, 2001). CASAFE is a private organization affiliated with CropLife, a global consortium of pesticide industry trade associations. It is responsible for gathering statistics on pesticide and fertilizer sales in Argentina, which are reported in annual reports on the agrochemical market. According to their 2000 report, glyphosate-based products accounted for 40.8% of the total volume of pesticides sold (CASAFE, 2000). This percent increased to 44% in 2003 (CASAFE, 2003).

Table 5. Top Ten Herbicides Sold in Argentina in 2003 (litres of formulated product)

	Concentration	Principle Crops	Sales in 2003
Glyphosate Products			
Glyphosate	48%	Soybeans	110,913,525
Glyphosate	74.8%	Soybeans	17,300,000
Glyphosate	62%	Soybeans	984,500
Glyphosate + Imazethapyr	24% + 2%	Soybeans	1,315,000
Atrazine	50%	Corn	8,252,220
2,4-D ester	100%	Soybeans, Corn	5,239,645
Acetochlor	90%	Corn	2,501,159
Acetochlor + Antidoto	84%	Corn	2,130,770
S-metolachlor & Atrazine	96% + 90%	Corn	1,456,000
Fluorcloridona	25%	Corn, ?	773,000
Total Top Ten Herbicide Products			150,865,819
Glyphosate Share of Top Ten			87%

Much like in the U.S., herbicides account for about two-thirds of total pesticide sales in Argentina (CASAFE, 2004). Table 5 presents an overview of the volume sold of the top-ten herbicide products in Argentina in 2003. Note that three different concentrations of glyphosate made the top ten. In addition, the top ten includes a combination product including glyphosate and imazethapyr. (See Appendix 2 for more detailed data on all major herbicides sold in Argentina from 1999 through 2003 and the basis for the estimates of herbicide use reported in this section). Products containing glyphosate accounted for 87% of the volume applied across the top ten-herbicide products in 2003. Moreover, glyphosate has accounted for virtually all the growth in the volume of pesticides applied in the country since 1995.

1. Roundup Use in Argentina, 1995 – 2004

Four major glyphosate based herbicide products have been sold in Argentina in recent years. These include three concentrations of glyphosate – 48% (by far the major product), 62%, and 74.8% concentrations. A combination product containing 24% glyphosate and 2% imazethapyr has also been among the top ten products sold in several years (CASAFE, 2004).

Limited official data are available on herbicide sales and use in Argentina and there is no data on herbicide use by crop. Accordingly, indirect methods must be used to project trends in glyphosate use in the production of RR soybeans. The most reliable national data on herbicide sales is compiled annually by CASAFE,[27] which reports pesticide sales by liters of formulated product at a given concentration level of active ingredient. Throughout this report, it is assumed that the volume of pesticide ***sales*** reported by CASAFE is the same as the volume of pesticide ***use***. CASAFE includes sales of both pesticides manufactured in Argentina and products that are imported.

Herbicide use on Roundup Ready soybeans in Argentina can be projected by drawing on CASAFE data on pesticide use, government data on the area planted to soybeans, reports and articles written by agricultural engineers familiar with weed management systems, and the results of private surveys and research projects. The basic approach is simple.

First, the number of RR soybean hectares produced each year is calculated based on the total hectares of soybeans planted and the estimated percent planted to Roundup Ready varieties. The average number of glyphosate applications on each hectare planted must be projected, along with the average rate of application measured in kilograms per hectare. These three estimates – RR hectares planted, average number of applications, and the average rate of application – are then multiplied together to produce an estimate of the total volume of glyphosate applied in a given year. The volume of other herbicides applied on RR soybean fields is projected in the same way. The above estimates can then be compared to the sales data reported by CASAFE. Each year, CASAFE reports the approximate share of herbicide sales accounted for by the "Glyphosate Phenomenon" and RR soybeans, a crop referred to as "the queen of Argentine agriculture" in CASAFE's 2000 report.

A survey of soybean producers in Argentina carried out in 2001 is another important source of information on actual field use of herbicides in the production of RR soybeans. The survey was designed and carried out by Dr. Matin Qaim, a researcher now with the University of Hohenheim in Stuttgart, Germany. Dr. Qaim's project was conducted jointly with a U.S. agricultural economist, Dr. Greg Traxler. Qaim and Traxler compiled data and conducted an analysis of the economic and environmental impacts of RR soybeans in Argentina. Fifty-nine farmers were surveyed in three provinces – Buenos Aires, Santa Fe, and Chaco (Qaim and Traxler, 2004). Most of the farmers surveyed had stopped growing conventional soybeans one to two years earlier, so the results reflect RR soybean production after one to three years of commercial use. The average farm surveyed was 496 hectares in size and produced 197 hectares of soybeans, suggesting that two-year rotations were common.

The Qaim and Traxler paper presents the only field level data that are publicly available on herbicide use on RR soybeans in Argentina. This data was relied upon in an analysis comparing the volume of herbicides applied on RR and conventional soybeans in the U.S. and Argentina. The results can be found in the paper "Economic and Environmental Impacts of First Generation Genetically Modified Crops: Lessons from the United States" (Benbrook, 2002), which was delivered at a December 2002 workshop in Buenos Aires. Table 6 below presents details on herbicide use on RR soybeans in the U.S. and Argentina and draws on data from the U.S. Department of Agriculture and the Qaim and Traxler survey.

Table 6 covers herbicide use on soybean acres planted using conventional tillage and no-till in 2000. In both countries, a higher percentage of no-till acres are planted to RR varieties than acres grown under conventional tillage and planting systems. The data in the last two lines in the table reflect overall RR soybean production in 2000. The estimates of the average number of applications and the average rate of application in Argentina were incorporated in this report's estimates of the volume of herbicide applications in the production of RR soybeans from 1995 through 2004.

[27] Access the CASAFE website at http://www.casafe.org/

Table 6. Adoption of Herbicide Tolerant Soybeans and Glyphosate Rates of Application in the United States and Argentina by Type of Tillage System: Crop Year 2000 Estimates						
	Soybean Hectares Planted	Percent Hectares Planted to RR Soybeans	Glyphosate Active Ingredient			
			Number of Applications	Average Rate of Application (Kg per hectare)	Kilograms Applied	Pounds Applied
Conventional/ Conservation Tillage						
Argentina	3,096,000	75.0%	1.9	1.10	4,852,980	10,708,600
United States	19,732,029	52.0%	1.1	0.67	7,585,638	16,721,069
No-till with Roundup Burndown						
Argentina	7,224,000	96.0%	2.5	1.20	20,805,120	45,890,061
United States	9,718,761	64.0%	2	0.78	9,754,207	21,501,258
All Tillage Systems						
Argentina	10,320,000	90.0%	2.3	1.20	25,634,880	56,653,085
United States	29,450,790	56.0%	1.3	0.76	16,330,907	38,685,976
Source: Benbrook (2002).						

On average soybean producers in Argentina made 2.3 glyphosate applications per year in 2000, compared to an average of 1.3 in the United States. The difference reflects the much greater percent of Argentina soybean hectares planted using the no-till system, compared to soybeans in the U.S. Essentially all no-till hectares are treated with a burndown application[28] of glyphosate herbicide soon before or at planting, as well as one or two applications during the season. In Argentina in 2000, about 30% of the RR soybean hectares required two treatments during the season, according to the Qaim and Traxler survey results.

The data on herbicide use in 2000 was combined with data from CASAFE on the volume of herbicides applied in 2000 to produce an estimate of the share of total glyphosate sales that were associated with RR soybeans. Total glyphosate sales in 2000 across all crops were 44 million kilograms, as shown in Appendix Table 3. In this appendix table, the liters sold of four glyphosate-based herbicides, as reported by CASAFE, are converted to kilograms of glyphosate active ingredient.

Table 7 shows the rapid increase in total herbicide use on soybeans from 1996/97 to 1999/2000, 2003/03 and 2003/04. The table reports the hectares planted to RR soybeans, the average rate of glyphosate application in kilograms of active ingredient, average number of applications, million kilograms applied, and the percent of glyphosate applied to soybeans. The volume of glyphosate applied to soybeans increased 145% from 1999 to 2003. Appendix Table 4 reports the same data for all years and describes data sources and assumptions used in making the estimates.

[28] In fields planted using the no-till system, early weeds that have begun growing must be chemically controlled prior to, or as part of the planting operation. The spraying of a broad-spectrum herbicide prior to planting is called a "burndown" application, since the chemical kills, or burns down, whatever weeds are then present and growing in the field.

Table 7. Changes in Herbicide Use Triggered by the Expansion of No-Till and Roundup Ready Soybeans in Argentina 1996 to 2004				
	1996/97	1999/2000	2002/03	2003/04*
Area Planted				
Million Hectares Planted to RR Soybeans	0.400	6.769	12.481	14.112
Glyphosate Applied				
Average Rate of Glyphosate Application (kg/hectare	1.14	1.2	1.26	1.30
Average Number of Applications	1.8	2.3	2.36	2.5
Million kgs of Glyphosate Applied to Soybeans	0.82	18.68	37.11	45.86
Percent Total Glyphosate Use on Soybeans	13.5%	63.8%	78.9%	69.9%
Other Herbicides on RR Hectares				
Percent Soybean Acres Treated	2.0%	10.0%	35.0%	45.0%
Average Rate of Application (kg/hectare)	0.30	0.40	0.60	0.65
Million kgs of Other Herbicides Applied	0.002	0.27	2.62	4.13
All Herbicides on RR Hectares				
Million kgs of Herbicide Applied to Soybeans	0.8	19.0	39.7	50.0
Notes:				
1. Hectares planted to RR soybeans are based on hectares planted to all soybeans in Appendix Table 1, coupled with ISAAA data on the percent of soybeans planted to RR varieties				
2. See Appendix Table 4 for sources of data and calculations regarding herbicide use.				

Figure 7 presents the volume of glyphosate applied on all crops and RR soybeans in millions of kilograms of active ingredient from 1995/96 through 2003/04. The 45.9 million kilograms of glyphosate applied on soybeans in 2003/04 is roughly equivalent to 100 million liters of formulated product that contains 48% glyphosate active ingredient by weight. From 1996 through 2004, the volume of glyphosate applied on all crops increased ten-fold. The increase from 2002/2003 to 2003/2004 was a remarkable 39 percent, reflecting a major recovery of the agrochemical sector, coupled with strong crop prices and rising farm incomes, according to CASAFE's summary for crop year 2003/04. Total glyphosate use on soybeans increased 56-fold from 1996/97 to 2003/04 and 24% from 2002/03 to 2003/04. The other rapidly growing use of glyphosate in recent years has been chemical fallow,[29] another use which often is associated with the expansion of the land base planted to RR soybeans (CASAFE, 2003).

Other herbicide use on RR soybean hectares is also estimated in Table 7 and accounted for less than 1% of total use in 1996/97, rising gradually to account for 8% of total use in 2003/04. These estimates of the volume of other herbicide active ingredients applied are likely conservative. As weed shifts and resistance become more widespread in Argentina and lessen the efficacy of glyphosate-based products, farmers will have to include other herbicides in their spray programs on a growing share of total RR hectares. Data from CASAFE in recent years on the volume of other soybean herbicides sold suggests that farmers have begun diversifying herbicide spray programs on RR soybean hectares. Since 2001 the volumes of several soybean herbicide active ingredients and burndown products other than glyphosate have gone up appreciably in Argentina –

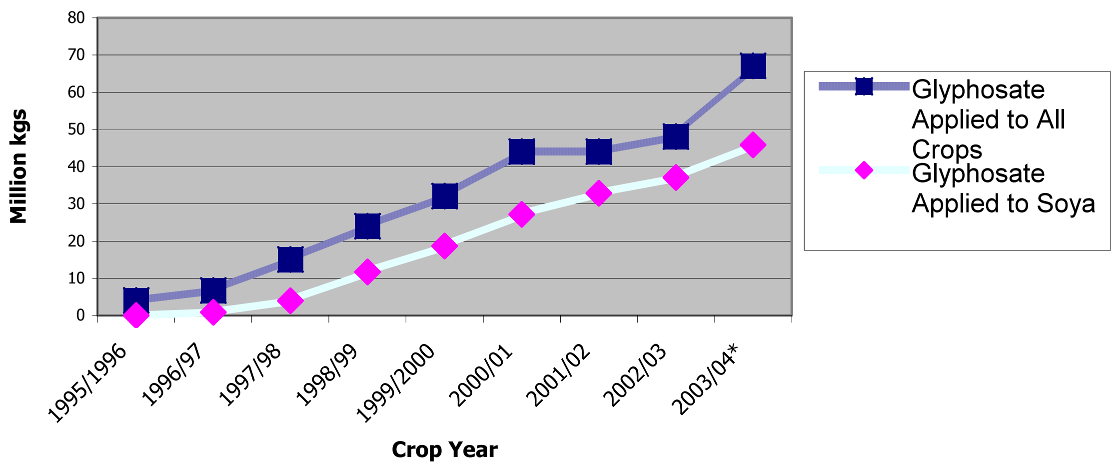
- Dicamba, volume applied up 157%;
- 2,4-D, volume applied up 10%; and
- Imazethapyr, over 50% increase.

In the U.S. the pesticide industry has responded to the widespread use of RR soybeans by offering farmers dozens of new, specially formulated herbicides mixtures designed to augment weed control in RR soybean fields. Pre-mix products have been aggressively marketed and priced competitively and have helped farmers avoid the need for two or more applications of glyphosate. A

[29] Chemical-fallow applications of herbicides in Argentina are typically made in the fall, prior to land remaining idle (or fallow) over the winter and as part of the process in clearing land of unwanted brush and other vegetation. The use of herbicides in a chemical-fallow treatment can be an alternative to field burning, mowing, tillage, or use of heavy equipment.

recent analysis of the impacts of herbicide tolerant crops on herbicide use in the U.S. estimated that 0.3 pounds of other herbicides were applied on the average acre of RR soybeans, accounting for about 20% of the total volume of herbicides applied per acre (Benbrook, 2004). Accordingly, U.S. farmers are relying about twice as heavily on other herbicides in managing weeds on their RR acres in contrast to farmers in Argentina.

Figure 7. Total Glyphosate Applied on All Crops and Soybeans, Argentina, 1995 - 2004



2. Weed Shifts and Resistance

Natural evolutionary forces and biological processes have been triggered by the Roundup Ready soybean system in both the U.S. and the Pampas region of Argentina. These forces have and will continue impacting both the composition of weed species and the effectiveness of glyphosate herbicide.

If farmers plant substantial acreage of the newly approved RR corn in rotation with RR soybeans, resistance will emerge much more quickly and spread far faster than it otherwise would.

Reliance year after year on a single herbicide, or a group of herbicides that work through the same mode of action, selects for phenotypes in weed populations that are less sensitive to the herbicide. The early stages of this process leads to the evolution of tolerant weeds that are only partially controlled by applications of the herbicide. Each year, some of these weeds survive and reach maturity, and set seed that can create more serious problems in future years. If and as farmers continue to spray the same herbicide more frequently and/or at higher doses, as recently the case in Argentina, the selection pressure on weed populations will increase and accelerate the emergence of genetically resistant phenotypes. Tolerance to glyphosate in certain weeds in Argentina has already been documented, including *Parietaria debilis, Commelina erecta, Ipomoea sp.,Oenothera indecora, Petunia axilaris, Verbena litoralis, Verbena bonariensis, Hybanthus parviflorus, Trifolium repens,* and *Convolvulus arvensis* and *Iresine diffusa* (Papa, 2004; Vitta et al., 2004; Puricelli et al., 2003; Faccini, 2000).

Resistant populations may already exist in some regions of the country. Without major changes in weed management systems, the number of weeds resistance to glyphosate in Argentina, and the levels of resistance, will rise in the future. If farmers plant substantial acreage of the newly approved RR corn in rotation with RR soybeans, the selection pressure placed on weed populations will be greatly intensified and as a result, resistance will emerge that much more quickly and spread far faster than it otherwise would. Plus, volunteer RR soybeans will pose a new weed management challenge for farmers growing RR corn.

There are just two ways to prevent or minimize problems with resistance: first, selection pressure must be reduced by cutting back on the use of glyphosate, and second, other herbicides and weed management methods must take on a greater share of the weed management burden.

Resistance has already become a serious problem in the U.S. Several common weeds have developed tolerance to glyphosate and one species, marestail, has become resistant.

This weed was first detected in 2000 in the State of Delaware in the eastern U.S. In four years glyphosate-resistant marestail has spread rapidly to the north and south, and west. It now infests millions of acres in over a dozen states and is forcing many farmers to make rescue treatments with 2,4-D and/or dicamba. It is interesting to note that CASAFE data show that these are two of the three soybean herbicides, other than glyphosate, that Argentina farmers are spraying more widely in recent years.

Glyphosate resistant marestail growing in a no-till soybean field in Indiana. (Photo courtesy of Purdue University Weed Science Department)

3. Changes in Soil Microbial Communities

Concern is growing in the U.S. over the recent increase in soybean plant disease problems and the stagnation of soybean yields. Many farmers suspect that there are linkages between the widespread planting of RR soybeans, the heavy use of glyphosate herbicide, changes in soil microbial communities, disease pressure and severity, and crop yields. By 1998, scientists had confirmed that Fusarium levels in the soil were increasing in some fields planted for multiple years to RR soybeans. Research since 1998 has shown that the increase in Fusarium levels has been triggered by the spraying of glyphosate herbicide and the impacts of glyphosate on the structure of soil microbial communities (University of Missouri, 2000). By 2000, the adverse impact of the RR soybean system on soybean root development and nitrogen fixation had been documented (King et al., 2001). In the last two years soybean Sudden Death Syndrome has become more common and is under intense investigation by many scientists. One hypothesis under review by scientists is that the genetic transformation of soybeans that makes them Roundup Ready also impairs the plant’s ability to respond to certain plant diseases, at least under certain sets of environmental conditions.

How might this come about? Plant root exudates following application of glyphosate may be providing an advantage to certain Fusarium strains relative to other fungi commonly found in soils. In other cases, applications of glyphosate may be directly impacting soil microbial communities, since glyphosate is known to be highly toxic to certain types of soil microorganisms. If populations of susceptible microorganisms crash following an application of glyphosate, this will lead to changes in the diversity and structure of microbial communities, and perhaps in the course of doing so, give certain Fusarium strains an opening to proliferate. Other mechanisms leading to a competitive advantage for certain Fusarium species are also likely involved under certain combinations of conditions, vastly complicating the task researchers face in sorting out interactions between soil types and conditions, planting systems, herbicide use, soil borne pests, and yield performance.

Impacts of RR technology on Fusarium-triggered diseases and food safety problems warrant careful attention in the U.S. and Argentina. One set of problems arises from elevated levels of Fusarium in corn harvested from fields previously planted to RR soybeans. Pseudopregnancy, a swine reproductive disease that leads to aborted pregnancies, has been linked to Fusarium contamination in corn. A team of university-based corn pest management experts in the U.S. recently analyzed the prevalence and severity of corn diseases. Fusarium-driven seedling, root and stalk rot was ranked the number one corn disease in terms of aggregate yield losses (Pike, 2002). *Fusarium graminearum* fungi trigger one of the most damaging diseases plaguing wheat farmers -- wheat scab, otherwise known as Fusarium head blight. This disease causes wheat kernels to shrivel up and appear bleached or scabby and triggers annual losses in the U.S. up to $1 billion.

Farmers in Argentina should also closely monitor changes in soil microbial communities and Fusarium species and levels (Coghlan, 2003). Wheat-soybean double cropping is a common practice in Argentina, as is wheat-soybean-corn rotations. The potential for Fusarium infection of wheat or corn in Argentina is very real, especially on farms using no-till planting systems for all crops planted (typically the case, for example, when wheat and soybeans are double cropped). This is because soil borne pathogens are much more likely to reach damaging levels in undisturbed soils. Wet conditions or moist locations in no-till fields are also known to favor growth of certain fungi.

A second agronomic and economic problem may emerge in Argentina from the impact of glyphosate applications on RR soybeans. A team of scientists at the University of Arkansas (King et al., 2000) has shown that root development, nodulation and nitrogen fixation is impaired in RR soybean fields and that the effects are worse under conditions of drought stress or in relatively infertile fields. The cause of these problems in RR soybeans stems from the impact of glyphosate herbicide on the bacterial symbiont responsible for nitrogen fixation in soybeans, *Bradyrhizobium japonicum*. Yield reductions up to 25% have been observed in the RR plots treated with glyphosate compared to conventional controls. Other things being equal –

- The more intense the use of glyphosate, the greater the likely impact on soybean plant root development and nitrogen fixation;
- Drought stress is likely to worsen adverse impacts on root development and N fixation; and
- The greater the reduction in root development and N fixation, the more vulnerable the plant to stress-induced yield losses, when compared to well managed conventional soybeans with healthy root systems and normal N fixation.

While soil nitrogen is not often a limiting resource in soybean production in the U.S., a growing percentage of soils in Argentina is losing fertility and may lack sufficient nitrogen to produce optimal soybean yields in fields where nitrogen fixation is impaired. A portion of the land producing soybeans in Argentina is newly converted pastures, rangelands, and forest. Soil organic matter levels would, in all likelihood, be relatively high in the first few years of soybean production, but would be expected to decline after three to five years in intensive agricultural production. The degree of changes in soil structure and nutrient availability would be determined by the effectiveness of erosion control practices, when and how field operations are carried out and their impact on compaction, and the adequacy of fertilization programs. If soil N levels do decline in Argentina, the adverse impacts of glyphosate applications in RR soybean systems may become more pronounced, reducing yields and increasing fertilization costs more sharply than currently the case.

4. Rust and Other Foliar Disease

Soybean rust is an extremely serious, relatively new soybean disease that has caused substantial yield losses in Paraguay and Brazil. It is also on the move. According to an Argentinean analyst, soybean rust will affect 25% of the soybeans in Argentina in 2004/05, reducing yields on some 3.5 million hectares (Adreani, 2004).

Soybean rust is caused by two fungal species. *Phakopsora pachyrhizi* is the Asian form of the disease and by far the most aggressive and damaging. The American form of the disease is caused by *Phakopsora* *meibomiae*. The fungi survive only in live plant tissue, which can include soybean plants and a wide range of alternate hosts, including several common weeds. Cool and humid weather accelerates infections, which can progress from barely visible signs of disease to 90% infected plant tissue in just two weeks. Disease spores move readily with the wind and can also be transported in trucks and farm equipment. Serious infections lead to partial or total plant defoliation and can dramatically reduce yields.

Asian soybean rust was detected in Brazil in 2001 and Paraguay in 2002. Losses in Brazil have ranged between 30% and 75% of normal yields and an estimated 90% of Brazil soybeans are infected to some degree. The disease cut soybean production by 4.5 million tons in Brazil in 2003/04, forced farmers to spend millions of dollars on fungicides of marginal effectiveness, and cost the nation's agricultural industry over $2 billion, double the losses from the year before (USDA, 2004c). Even greater losses have been reported in Australia and India. In November 2004, soybean rust was for the first time detected in the U.S., in the state of Louisiana (Feedstuffs, 2004).

"Argentina is surrounded by countries that have suffered serious damage due to Asian soy rust disease."
-- INTA Regional Centre Santa Fe, 2004

Soybean rust was first detected in Argentina in 2002 in Chaco and Misiones, according to an update on the disease by INTA scientists (Ivanovich et al., 2004). The disease "erupted" in the province of Santa Fe in April 2004 and impacted soybeans virtually throughout the province that year (INTA Regional Centre Santa Fe, 2004). Given that Santa Fe province accounts for about 27% of soybean production in the country, this infestation caused serious alarm throughout the soybean industry and in government circles.

According to INTA, the options for managing the disease are planting resistant varieties – but none exist – and spraying fungicides. INTA's recommendations for action focus on monitoring fields to assure early detection of the disease, improved diagnostic infrastructure, and training on the biology of the disease, but do not mention other proven strategies including, most obviously, planting fewer soybeans, diversifying rotations, and controlling alternate hosts more effectively.

The spread of this serious disease in Argentina has triggered major marketing and advertising campaigns by fungicide manufacturers hoping to expand sales. BASF, Bayer and Syngenta are promoting use of several fungicides known to slow the spread and limit the damage of the disease. Millions of dollars will be spent on fungicide applications in Argentina in the absence of the research needed to determine the optimal rates of applications, mixtures of products, and timing. Inevitably, growers lack the knowledge and experience needed to separate marketing hype from reliable information. According, some applications are likely to be made either too late to make much of a difference or in ways that lessen their effectiveness. In addition, the rush to try to combat this disease has left no time to consider longer term environmental and public health consequences. Given growing evidence that the application of glyphosate in the RR system is changing soil microbial communities and disease pressure, it will be important to monitor the ecological impacts triggered by fungicides as they become a routine part of the cropping system.

The economic impacts of soybean rust disease could emerge as significant in driving competitive advantage around the world. Any country or producing region that has to rely routinely on fungicide applications to manage ***any*** soybean disease will suffer a blow to efforts to remain internationally competitive. Fungicide treatment will increase cash costs at least 15% and could easily push costs up 25% or more (EEAOC, 2004). Such an increase will be hard to absorb without offsetting cuts in other costs, smaller profit margins, or new government price supports. While U.S. and European soybean farmers are also facing new sorts of diseases and production problems, their efforts to alter management systems in ways that reduce the prevalence and severity of such problems are supported by relatively well-funded public research, education, and plant breeding programs. It is inconceivable that U.S. soybean farmers will accept the need to spray either insecticides or fungicides on soybeans as a routine part of pest management systems. Occasionally new pests will emerge, like the Asian aphid that has been such a problem in the last three years. While this insect has triggered substantial insecticide applications in some regions since 2002, its numbers are down this year and methods to reduce populations are under active exploration.

One of the great virtues of the soybean as an agronomic crop over the last 50 years is its ability to naturally defend itself against insects and diseases, especially when plant breeders remain focused on developing varieties with resistance to major and emerging pests. In most years in the U.S., only some 200,000 and 400,000 pounds of insecticides are applied to the entire U.S. 30 million hectare-plus soybean crop, representing a tiny fraction of a pound per hectare. Fungicide use is even less common; essentially none is applied. The emergence of herbicide tolerant technology in the mid-1990s has lessened the emphasis placed on insect and disease resistance by plant breeders. There are growing signs that many public and some private sector plant breeders are reconsidering soybean research and breeding priorities with the goal of increasing focus on the management of a range of problems brought on or made worse by the rapid growth in the planting of RR soybeans. A combination of new varieties with higher levels of resistance and changes in cropping practices will almost certainly continue to suppress soybean pest populations in the U.S. such that only a few percent of the hectares planted in a given year are treated with insecticides or fungicides, as has been the case for decades.

Cultivating for weed control in a soybean ridge-tilling system. (Photo by Keith Weller, courtesy of USDA/ARS)

F. Conclusions

Four factors explain the popularity of Roundup Ready soybeans in Argentina, especially when coupled with no-tillage planting systems.

- This method of growing soybeans is simple. Planting entails a single pass through the field with just a planter, instead of multiple passes with much larger and varied equipment. Instead of juggling multiple herbicides, a single product controls all, or most weeds.

- The RR system is flexible and forgiving. It provides farmers more options to work around the weather and to catch up when schedules slip. If an applicator makes a mistake and applies one-half, or double the proper rate of glyphosate on a given field, the consequences will not likely be serious.

- The system delivers reliable and cost-effective weed management, especially in contrast to alternative systems and technology. It has been especially profitable in Argentina where growers have had access to relatively inexpensive imported glyphosate-based herbicides and have not had to pay a premium for most RR seed.

- This method of growing soybeans greatly simplifies the logistical hurdles and farm labour challenges faced by very large operations. It is a highly homogenous, industrial approach to farming that requires a narrower skill set among workers and managers, and much smaller and less costly machinery.

Argentina's agricultural sector, and indeed much of its economy, has become dependent on continued success in world soybean markets. Future success is by no means assured. Growers in Argentina and Brazil are facing a serious new rust disease that is triggering substantial fungicide spraying, much of questionable efficacy. Little is known about the agronomic, environmental, and public health impacts of the fungicides now being widely promoted as a tool in managing rust disease.

Soybean farmers are facing more serious insect pest pressure than just a few years ago. Several weed species have evolved a higher level of tolerance to glyphosate and some may be technically resistant, even though scientists have yet to confirm, or at least publicly acknowledge, the presence of resistance. Given the almost total reliance on glyphosate for soybean weed management in Argentina, resistance will surely emerge and become progressively serious and costly. The important question is not whether Argentina's soybean farmers will have to contend with resistant weeds, but how well they will do so and at what cost. The current level of official and unofficial denial of the threat of resistance is worrisome and suggests that remedial actions will be delayed and timid. Argentina's farm leaders and scientists should closely follow the well-documented and widely studied spread of glyphosate resistant marestail in the U.S. to gain a better understanding of what is at stake and the potential costs if the first signs of resistance are missed or ignored.

Growth in soybean production has come at a heavy price. The land area planted to soybeans in Argentina has increased 6.2 million hectares since 1996. About 25% of this new land has come from the conversion of cropland growing wheat, corn, sunflowers, and sorghum. Another 7% has come from other crops including rice, cotton, beans and oats. Former cattle pastures and hay fields have been the source of another 27%. The balance – some 41% – has come from the conversion of wild lands, including forests and savannahs.

Further growth in the industry will likely come mostly from the conversion of pastures and forages now supporting the cattle industry and from additional forest conversion. Some of the more marginal lands planted to soybeans in recent years will likely revert to pasture, returning to soybeans only when market prices are high or rising. The environmental damage of further soybean expansion will steadily increase and the economic benefits will gradually decline as yield levels fall and average costs increase on more marginal lands in areas with less favourable soils and weather.

Glyphosate herbicide use will continue to increase for the foreseeable future, perhaps dramatically if farmers are as enthusiastic about Roundup Ready corn, just recently approved in Argentina, as they have been about RR soybeans. Unfortunately though, reliance year after year on a single herbicide accelerates weed shifts and the emergence of genetically resistant weeds. The threat posed by resistance in Argentina will exponentially increase if Roundup Ready corn is widely planted in rotation with RR soybeans. In addition, volunteer RR corn will emerge as a new weed in RR soybeans, and volunteer RR soybeans will be a new weed in RR corn fields.

The honeymoon period for Argentina's soybean industry is drawing to a close. Costs are rising on multiple fronts and serious biologically-based and soil fertility production problems are now evident. Questions linger over the impact of glyphosate on the structure and function of soil microbial communities and the severity of new soybean plant diseases and insect pests. The future competitiveness of Argentina's soybean industry will rest on how thoughtfully and decisively these problems are confronted.

To sustain today's levels of production, serious soil quality, grain quality, and environmental problems must be confronted. So too must the social consequences of Argentina's soybean "Gold Rush." The expansion of soybean production since the early 1990s has transformed the countryside, created a new generation of wealthy farmers, altered the nation's diet and nutritional status, and displaced millions of people and communities in the wake of the rush to expand soybean production. Social problems must be addressed in order to prevent more serious problems in the future.

The well being of a nation may well rest on whether ways are found to reverse the current state of dependency of the agricultural sector, and indeed the whole country on soybean production. More of the same will prove disappointing, and perhaps disastrous. Still, some people and agribusiness leaders will continue to deny the existence of biological and ecological problems in the Argentinean soybean sector. To the extent they persuade the government, farmers, and agribusiness to stick with the status quo, proven and practical changes in production systems will be delayed and the vulnerability of the sector will grow.

G. Bibliography

AACREA, 2003. El libro de la Soja, 2003, Buenos Aires.
Adriani, P. 2004. Nubes sobre la soja en EE.UU. *La Voz del Interior on line,* 20th August 2004. http://www.lavozdelinterior/2004/0820/suplementos/lavozdelcampo/nota264834_1.htm
Backwell, B., Stefanoni, P. 2003. El Negocio del hambre en la Argentina. *Le Monde Diplomatique - El Dipló*, February 2003.
Begenisic, F. 2002. SAGPyA – Secretaría de Agricultura, Granadería, Pesca y Alimentos. 2002. El quinquenio de la soja transgenica. September 2002. http://www.sagpya.mecon.gov.ar/new/0-0/prensa/publicaciones/agricultura/SOJA.PDF
Benbrook, C. 1999. Evidence of the Magnitude of the Roundup Ready Soybean Yield Drag from University- Based Varietal Trials in 1998. *Ag BioTech InfoNet Technical Paper,* Number 1, 13th July 1999. http://www.biotech-info.net/RR_yield_drag_98.pdf
Benbrook, C. 2002. Economic and Environmental Impacts of First Generation Genetically Modified Crops: Lessons from the United States". Presentation at the workshop *Transgenics in Argentine Agriculture: Towards Defining a National Policy* in Buenos Aires, Argentina, 5th December 2002. [Workshop sponsored by the International Institute for Sustainable Development (IISD) and the Institute for Interamerican Cooperation in Agriculture (IICA).] http://www.iisd.org/pdf/2002/tkn_gmo_imp_nov_02.pdf
Benbrook, C. 2004. Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years. *Ag BioTech InfoNet Technical Paper,* Number 7, 25th October 2004. http://www.biotech-info.net/technicalpaper7.html
CIARA - Cámara de la Industria Aceitera de la República Argentina. 2003. Capacidad Instalada de Molienda por Empresa 2003. http://www.ciara.com.ar/infoindu.htm
Cap, E., González, P. 2002. Argentina: Una Exploración de la Frontera de Posibilidades Productivas del Sector de Granos y Oleaginosas (Segundo Borrador). INTA - Instituto Nacional de Tecnología Agropecuaria, IES - Instituto de Economía y Sociología. July 2002. http://www1.inta.gov.ar/ies/publicaciones%5Cfrontera.pdf
CASAFE - Cámara de Sanidad Agropecuaria y Fertilizantes. 2003 and earlier years. Estadísticas. http://www.casafe.org.ar/mediciondemercado.html
CASAFE – Cámara de Sanidad Agropecuaria y Fertilizantes. 2004. Estadísticas. http://www.casafe.org.ar/mediciondemercado.html
Casas, R. 2003. Los 100 millones de toneladas al alcance de la mano. INTA - Instituto Nacional de Tecnología Agropecuaria, Instituto de Suelos, May 2003. http://www.insuelos.org.ar/Informes/Los100millones.htm
China People's Daily Online. 2004. China wins glyphosate anti-dumping case in Argentina. 6th February 2004.
Clarín. 2004. Kirchner firmó el decreto para cambiar los planes sociales. 29th October 2004. http://www.clarin.com/diario/2004/10/29/elpais/p-01001.htm
Coghlan, A. 2003. Weedkiller may encourage blight. *New Scientist*, Vol. 179, issue 2408, 16th August 2003.
Consejo Nacional de Coordinación de Políticas Sociales. 2003. Consideraciones sobre la soja en la alimentación. Febrero 2003. http://www.desarrollosocial.gov.ar/pea/descarga/cons_soja.pdf
CREA. 2004. La sustentabilidad del negocio agrícola. June 2004. http://www.aacrea.org.ar/soft/nro284.htm
Dellatorre, R. 2004. Ver los beneficios de la sojización. *Pagina 12, Cash supplement*, 21st March 2004, p.12.
EEAOC – Estación Experimental Agroindustrial Obispo Colombres, INTA. 2004. In: *La Gaceta Online*. 2004. Anticipan una fuerte baja en la rentabilidad de la soja. 5th November 2004. http://www.lagaceta.com.ar/vernota.asp?id_nota=92282
Eliason, R., Jones, L. 2004. Stagnating National Bean Yields (?). Presentation, Midwest Soybean Conference, Des Moines, Iowa, August 7, 2004. Accessible at – http://www.iasoybeans.com/whatnew/msc04/proceedings/roneliason%20.ppt
Elmore, R.W., F. W. Roeth, Lenis A. Nelson, Charles A. Shapiro, Robert N. Klein, Stevan Z. Knezevic, and Martin, A. 2001. Glyphosate-Resistant Soybean Cultivar Yields Compared with Sister Lines. Agronomy Journal, Vol. 93: 402-411.

http://screc.unl.edu/Research/Glyphosate/glyphosateyield.html
European Commission. 2001. Use of processed animal proeins in animal feed SANCO/1531/2001 rev. 1 – *Working Document of the Commission Services – Food Safety*. http://europa.eu.int/comm/food/fs/bse/bse28en.html
Faccini, D. 2000. Los cambios tecnológicos y las nuevas especies de malezas en soja. Universidad de Rosario, *AgroMensajes* No 4 pag. 5, December 2000.
Feedstuffs. 2004. USDA detects soybean rust in Louisiana. *Feedstuff News Flash*, 10th November 2004.
FIAN – FoodFirst Information and Action Network, and EED – Evangelischer Entwicklungsdienst. 2003. Report of the International Fact Finding Mission to Argentina, April 2003.
Franco, D. 2004. Aceite de Soja - Análisis de Cadena Alimentaria. *Dirección Nacional de Alimentación*. http://www.alimentosargentinos.gov.ar/0-3/olea/Aceite_Soja-r19/A_soja.htm
Global Agro S.A. 2003. Cada centavo vale millones. *Fortuna*, edition 46.
http://www.fortuna.uolsinectis.com.ar/edicion_0046/sociedad/nota_00.htm
Horstmeier, G.D. 2001. Right Seed for the Job. *Farm Journal*, January, 2001.
Huergo, H.A. 2002. In: Ibáñez, L. 2002. *La Gente*, No. 1906, 29th January 2002.
Huergo, H.A. 2003. Así, la soja es peligrosa. *Clarin, Suplemento Rural*, 9th August 2003. http://old.clarin.com/suplementos/rural/2003/08/09/r-01001.htm
Argañaraz, N. 2004. Coparticipación Federal de Impuestos: La Verdadera Historia. IERAL, Fundacion Mediterranea http://falcom.bolsamza.com.ar/ieral/charlas/junio_2904_1.pdf
INDEC – Instituto Nacional de Estadística y Censos. **2002.** Censo Nacional Agropecuario (Agricultural national census) - Definitive Results. http://www.indec.gov.ar/proyectos/cna/cna.asp
INDEC – Instituto Nacional de Estadística y Censos. 2004. Pobreza. http://www.indec.gov.ar/
INDEC – Instituto Nacional de Estadística y Censos. 2004a. Exportaciones según complejos exportadores. http://www.indec.gov.ar/nuevaweb/cuadros/19/expserieajust.xls
INDEC – Instituto Nacional de Estadística y Censos. 2004b. In: Muscatelli, N. 2004. Se necesitan $734 para no ser pobre. *Clarín*, 8th October 2004.
http://www.clarin.com/diario/2004/10/08/elpais/p-02401.htm
INTA - Instituto Nacional de Tecnología Agropecuaria. 2003. El INTA ante la preocupacíon por la sustentabilidad de largo plazo de la produccíon agropecuaria Argentina. December 2003. http://www.inta.gov.ar/info/documentos/sustentabilidad.pdf
INTA - Instituto Nacional de Tecnología Agropecuaria - Regional Center Santa Fe. 2004. Campaña Provincial de alerta temprana de la Roya de la Soja: Organizándonos para minimizar su impacto. http://www.inta.gov.ar/rafaela/info/documentos/crsantafe/roya%5Fsoja.htm
INTI – Instituto Nacional de Tecnología Industrial. 2004. Causas y riesgos del monocultivo de soja. http://www.inti.gov.ar/sabercomo/sc16/inti42.php
ISAAA – International Service for the Acquisition of Agri-biotech Applications. 2004 and previous years. Global Status of Commercialized Transgenic Crops. http://www.isaaa.org
Ivancovich, A., Botta, G. 2004. La roya de la soya en la Argentina. INTA, Miscellanous Papers No. 102.2004.
http://www.sagpya.mecon.gov.ar/new/0-0/agricultura/otros/royadelasoya/RoyaRevista%20inta.pdf
Karr-Lilienthal, L.K., Grieshop, C.M., Merchen, N. R., Mahan, D.C. and Fahey, G.C. 2004. Chemical Composition and Protein Quality Comparisons of Soybeans and Soybean Meals from Five Leading Soybean-Producing Countries. J. Agric. Food Chem**.,** 52: 6193-6199
King, C., Purcell, L., and Vories E. 2001. Plant growth and nitrogenase activity of glyphosate-tolerant soybeans in response to foliar application. *Agronomy Journal*, Vol. 93: 179-186. http://agron.scijournals.org/cgi/content/full/93/1/179
La Capital. 2003. Afip investiga a siete grandes cerealeras. 16th July 2003. http://www.lacapital.com.ar/2003/07/16/economia/noticia_19365.shtml
La Capital. 2004. Campos y Buzzi se tiran con la tierra. 31stJuly 2004.
http://www.diariolacapital.com/2004/07/31/campo/noticia_120337.shtml
Longoni M. 2004. La soja se convirtío en un imán para las inversiones. *Clarin*, 10th March 2004, p. 19
Longoni, M. 2004a. Exportadores de granos, en guardia. *Clarin*, 26th. July, 2004.
http://www.clarin.com/diario/2004/07/26/elpais/p-01701.htm
Lopez, G.M. 2003. Podremos manejar una cosecha de 100 millones? Limitantes Estructurales del Sector Granario Argnetino. *Fundación Producir Conservando*. September 2003. http://www.producirconservando.org.ar/docs/servicios/documentos.htm

Maino, M. 2003. Fundación para el Cambio. 2003. El peso de la soja en la Economía Argentina. November 2003. http://www.paraelcambio.org.ar/documentos/15-soja.pdf
Martelotto, H., Salas, H., Lovera, E. No date. El Monocultivo de Soja y la Sustentabilidad de la Agricultura Cordobesa. *INTA - Instituto Nacional de Tecnología Agropecuaria - Regional Center Menfredi.*
http://www.fertilizar.org.ar/articulos/El%20Monocultivo%20de%20Soja%20y%20la%20Sustentabilidad%20de%20la%20Agricultura%20Cordobesa.htm
MECON - Ministry of Economy and Production. **2002.** Agricultural Sector Indicators. http://www.mecon.gov.ar/peconomica/basehome/infoeco_ing.html
MECON - Ministerio de Economia Argentina. 2004. Recaudacion Tributaria - 2003 vs 2002. 2004. http://www.mecon.gov.ar/download/rec_trib/2003.xls - http://www.mecon.gov.ar/sip/rec_trib/4trim03/Cuadro1.xls
Michelena, R., Rivero, E., Irurtia, B., Rímolo, M. y M. Rorig. 2000. Descomposición de rastrojos en siembra directa y su influencia en la fertilidad y en el control de la erosión. 8° Congreso Nacional de AAPRESID. Tomo I: Conferencias. Mar del Plata
http://www.inta.gov.ar/suelos/investiga/eval_siembra_directa.htm
Ministerio de Salud y Ambiente. 2004. Forest Map for Salta province (Mapa Forestal Provincia de Salta), 2002 update. *Secretaría de Ambiente y Desarrollo Sustentable,* March 2004.
Oliverio. G., Segovia, F., López, G.M.. 2004. Fertilizantes para una Argentina de 100 millones de tns. *Fundacion Producir conservando*, Junio 2004. http://www.producirconservando.org.ar/
Palermo, A. 2004. Inquieta el abastecimiento del glifosato. *La Nación*, 27th March 2004, p. 9.
Papa, J. C. M. 2004. Malezas tolerantes y resistentes a herbicidas. Presentation at Seminar *Sustentabilidad de la Produccion Agrícola*, in Buenos Aires, Argentina, 29th and 30th March 2004.
Pengue, W. 2001. Cultivos Transgenicos ¿Hacia dónde vamos? Lugar Editorial, Buenos Aires, ISBN 9508921072, p. 154. 2001.
Pengue, W. 2004. La Pampeanization de Argentina. *Le Monde Diplomatique*, No. 61.
Persoglia S. 2004. Preocupa la baja de la soja. Clarín. 14th October 2004. http://www.clarin.com/diario/2004/10/14/elpais/p-849580.htm
Pike, D.R. 2002. Field Corn Pest Management Plan, North Central Region. August 14, 2002.
Puricelli, I., Faccini, D., Tenaglia, M. and Vergara, E. 2003. Control de Trifolium Repens con distintas dosis de herbicidas. *Siembra Directa*. Aapresid, year 14, No. 70, p. 39/40, December 2003.
Qaim, M., Trax er, G. 2002. Roundup Ready Soybeans in Argentina: Farm Level, lEnvironmental, and Welfare Effects. Paper presented at the 6th ICABR Conference on "Agricultural Biotechnologies: New Avenues for Production, Consumption and Technology Transfer, Ravello, Italy, July 2002.
Qaim, M., Traxler, G. 2004. Roundup Ready soybeans in Argentina: farm level and aggregate welfare effects. *Agricultural Economics*, doi:10.1016/j.agecon.2003.04.002.
Reca, A. 2001. Oilseed crushing industry in Argentina: Increasing supplies, better margins & further restructuring. *Industry Note - Food & Agribusiness Research*, Issue 028-2001, Rabobank International. September 2001. http://www.rabobank.com/Attachments/U.S.-IN-028-2001_Oilseed_Crushing_Industry_in_Argentina_Alejandro_Reca_FAR_September2001.pdf
Rocha, L. 2004. Un país que pierde sus montes. La Nación. 17th. Augost 2004.
SADESO - Sociedad Argentina para el Desarrollo y Uso de la Soja. 2002. El hombre, los alimentos y la salud. Campaign leaflet.
SAGPyA – Secretaría de Agricultura, Granadería, Pesca y Alimentos. 2004. Estimaciones Agrícolas – Oleaginosas. http://www.sagpya.gov.ar/http-hsi/bases/oleagi.htm
SAGPyA – Secretaría de Agricultura, Granadería, Pesca y Alimentos. 2004a. Definieron plazos para la Ley de Fondo de Compensación Tecnológica. Press release, 22nd September 2004.
SAGPyA – Secretaría de Agricultura, Granadería, Pesca y Alimentos. 2004b. Elaboración propia en base a datos suministrados por terminales portuarias. *Dirección de Mercados Agroalimtarios*.
SAGPyA – Secretaría de Agricultura, Granadería, Pesca y Alimentos, and FAO – Food and Agriculture Organisation. 2004. Determinación de las Inversiones Necesarias para la Segregación de Maíz y Soja no OVM. Documento 4 - Project TCP/ARG/2903, Junio 2004. http://www.sagpya.mecon.gov.ar/new/0-0/programas/fao_sagpya/Documento%204.pdf
SAGPyA –SAGPyA Secretaría de Agricultura, Granadería, Pesca y Alimentos. 2004c. FOB oficiales. October 2004. http://www.sagpya.gov.ar/new/0-0/agricultura/diario/fobanto/fob.htm
Smith, T. 2004. Argentina: Soy Exports Are Up, Monsanto is Not Amused. *New York Times,* 21st January, 2004.
Soja Solidaria. 2003. Listado de personas e instituciones donantes del Plan Soja Solidaria. http://www.sojasolidaria.org.ar/images/ss_p%20-%20Donaciones%20Realizadas.xls

Soja Solidaria. 2003a. Balance de Resultados – Sede Rosario. http://www.sojasolidaria.org.ar/images/Soja%20Solidaria%20-%20Balance%20al%2014-11-03%20Rosario.xls
Tiempo Agropecuario. 2004. Campos llamó a duplicar la produccion granaria en 15 anos. 5th July 2004.
Trigo, E., Chudnovsky, D., Cap, E., and A. Lopez. 2002. Los transgenicos en la agricultura Argentina – Una historia con final abierto. Libros del Zoral.
UNER – Facultad de Ciencias Agropecuarias, Dirección de Silvicultura y Monte Nativo. 2003. Prov. ER. Mapa preleminar de la superficie ocupada. Relevamiento 2003.
University of Missouri. 2000. "MU researchers find fungi buildup in glyphosate-treated soybean fields." Press release, December 21, 2000. Accessible at
http://www.biotech-info.net/fungi_buildup2.html
USDA – U.S. Department of Agriculture. 2002. Argentina Agricultural Situation Argentina's Economic Crisis: For Better AND Worse. *Foreign Agriculture Service GAIN Report,* AR2054, 16th October 2002. http://www.fas.usda.gov/gainfiles/200210/145784261.pdf
USDA – U.S. Department of Agriculture. 2003. Argentina – Planting Seeds Annual 2003. *Foreign Agriculture Service GAIN Report,* AR3016, 29th April, 2004. http://www.fas.usda.gov/gainfiles/200304/145885447.pdf
USDA – U.S. Department of Agriculture. 2004. Argentina Oilseeds and Products Annual 2004. *Foreign Agriculture Service GAIN Report,* AR4026, 26th April 2004. http://www.fas.usda.gov/gainfiles/200405/146106239.pdf
USDA – U.S. Department of Agriculture. 2004a. Production, Supply & Distribution Online (PSD Online). *Foreign Agriculture Service*. http://www.fas.usda.gov/psd/intro.asp?circ_id=2
USDA – U.S. Department of Agriculture, 2004b. Oilseed Prices – Soybeans. October 2004. http://www.fas.usda.gov/oilseeds/circular/2004/04-10/toc.htm
USDA – U.S. Department of Agriculture, 2004c. Soybean Producers see decreasing margins in Brazil. *Foreign Agriculture Service GAIN Report*, BR4622, 24th September 2004.
Vitta, J.I., Tuesca, D., Puricelli, E. 2004. Widespread use of glyphosate tolerant soybean and weed community richness in Argentina. *Agriculture, Ecosystems & Environment*, doi: 10.1016/j.agee.2003.10.016.

Appendix 1. Estimates of Land Use Changes in Argentina Triggered by the Expansion in Soybean Production

A detailed overview of land use changes in Argentina associated with the expansion in soybean hectares planted is provided in Appendix Table 1. The table coves the period 1992 through 2003, although most of the discussion in the report focuses on the period after 1996, the year Roundup Ready soybeans were first widely planted in Argentina.

The hectares planted annually to soybeans, other major crops, and other crops are from official government figures provided by SAGPyA (Secretaría de Agricultura, Ganadería, Pesca y Alimentos, http://www.sagpya.mecon.gov.ar/new/0-0/agricultura/index.php). Trends in the total hectares planted to ten major crops are noted in the line "Total, Major Land Uses." The following line reports the total cropland base, excluding soybeans, and shows that in the early years of the expansion, both the hectares planted to soybeans and other major crops increased. But by 1997, the expansion of soybeans began to cut into other crops, which fell from a peak of 18.8 million hectares in 1996/97 to 13.2 million in 2003/04.

During the period of expansion in soybean production, newly planted soybean hectares came from four sources:

- Conversion to soybeans of hectares previously planted to other crops;
- Conversion of pasture or forage production fields to soybeans;
- The double-cropping of soybeans with wheat (i.e., the same hectare produces wheat and soybeans in the same crop year); and
- The clearing of forests, savannahs, and other wild areas to cultivated cropland.

The hectares devoted to the double-cropping of soybeans are estimated in the line "Double-crop Hectares Planted." An estimate for the hectares of double-crop wheat-soybeans produced in 2001/2002 was provided by the Fundacion Producir Conservando, in a report entitled "Podremos manejar una cosecha de 100 milliones?" (Lopez, 2003). In this report, it is estimated that 2.2 million hectares of "second soy" was planted annually from 1998/99 through 2002/03. In the table, the hectares planted under a wheat-soybean double-cropping system average 2.2 million hectares over this time period, with the double-crop hectares planted steadily increasing from 650,000 hectares in 1998/99 to 2,800,000 hectares in 2003/04. Over the 12-year period, the percent of total soybean hectares planted in a double-crop system is estimated to increase gradually from 6% to 21%.

The line "Soybeans Minus Double-crop Hectares" is the land area planted to just soybeans annually. All hectares planted to a wheat-soybean double-crop are therefore counted under the wheat line in the table.

The land area newly planted to just soybeans is then estimated and reported in the line "Land Newly Planted to Soybeans." This line reports the total number of hectares newly converted to soybean production each year from one of the sources noted above. The last four lines in Appendix Table 1 provide estimates of the hectares of major crops, other crops, pasture or forage land, or forests/savannahs that were converted each year to support the expansion of soybean production.

The estimates of forest/savannah conversion are described in Table 3 and accompanying text. Data from government sources are available to estimate an average conversion in seven provinces of 272,000 hectares annually from 1998 through 2001/02. In the Appendix Table, it was assumed that the rate of conversion was steady during this period, when in fact it likely accelerated through the five-year period. The hectares converted in 2003 and 2004 were estimated based on the substantial increase in soybean area planted from 2001/02 to 2003/04 – some 2.6 million hectares. The land area devoted to all major crops increased in this same period some 823,000 hectares, which is about equal to the estimate of forest conversion in Table 3 for 2003 and 2004.

Conversion of forest/savannah from 1996 through 2004 is estimated to account for about 41.7% of the land area newly devoted to soybean production. Conversion of hectares producing major crops accounted for another 24.5%, with minor crops adding 7% and pastures/forage about 26.7%. In all likelihood, the estimates of conversion in 2003 and 2004 are conservative, given the major expansion of soybean production and the substantial land area devoted to other crops and pasture/forage had already been converted to soybeans in the previous five years.

The estimates of the land area converted from major crops, other crops and forage and pasture production are based on trends in hectares planted by year. These are rough estimates, based on the assumption that in the early years of the expansion, relatively more cropland would be converted, compared to the clearing of forests, which is a costly activity. In the later years, it was assumed that relatively less hectares of major crops were converted, and that reductions in pasture and forage production and forest conversion accounted for a progressively greater portion of the new land planted to soybeans. While there is considerable uncertainty in the disaggregation of the conversion data across major crops, other crops, and pasture/forage, the estimates of new land planted to soybeans each year and forest conversion are the most important and are likely close to actual values.

Notes accompanying Appendix Table 1 below --

In the calculations of the previous use of land newly planted to soybeans (last four lines in the table), it is assumed that the sum of the land use changes in each year equals the hectares reported in the row "Land Newly Planted to Soybeans." This reflects the assumption that land converted from forest in a given year is also planted to soybeans in the same year. In actual practice, land clearing requires several steps that typically require one to two years to complete. The year-to-year values for conversions from major crops, minor crops, pasture/forage, and forest therefore misrepresent the actual land use changes in a given year, but over the nine years from 1996, the total hectares converted from the major land uses are reliable estimates of total land use change. Given uncertainties in the percentage of agricultural land converted from major versus minor crops, and from cultivated cropland in contrast to forage land and pastures, the greatest confidence can be placed in the estimates of new land planted to soybeans; the sum of major crops, minor crops, and pasture/forage converted to soybeans; and, the hectares of forest converted to soybeans.

Appendix Table 1. Land Use Changes in Argentina Linked to the Expansion of Soybean Plantings: Estimates of Changes in Hectares from 1992 to 2004 (see addendum for sources and assumptions)

Area Devoted to Major Land Uses (hectares)	1992 - 1993	1993 - 1994	1994 - 1995	1995 - 1996	1996 - 1997	1997 - 1998	1998 - 1999	1999 - 2000	2000 - 2001	2001 - 2002	2002 – 2003	2003 – 2004*	Totals 1996 – 2003/04
Soybeans	5,319,660	5,817,490	6,011,240	6,002,155	6,669,500	7,176,250	8,400,000	8,790,500	10,664,330	11,639,240	12,606,845	14,226,000	80,172,665
Wheat	4,547,700	4,910,000	5,308,000	5,087,800	7,366,850	5,918,665	5,453,250	6,300,000	6,496,600	7,108,900	6,300,210	6,036,000	50,980,475
White Wheat	40,700	34,800	43,500	54,800	82,600	81,300	73,700	69,800	67,800	47,350	42,500	46,600	511,650
Sorghum	809,900	670,380	621,860	670,680	804,450	820,060	879,800	819,005	698,170	591,982	592,740	544,000	5,850,207
Corn	2,962,820	2,781,380	2,957,700	3,414,550	4,153,400	3,751,630	3,270,250	3,651,900	3,494,523	3,061,661	3,084,374	2,860,000	27,327,738
Sunflower	2,187,100	2,205,800	3,010,440	3,410,600	3,119,750	3,511,400	4,243,800	3,587,000	1,976,120	2,050,365	2,378,000	1,835,000	22,701,435
Other Crops													
Rice	144,100	148,200	188,520	211,400	226,573	247,500	290,850	200,700	153,732	126,435	135,170	172,000	1,552,960
Oats	2,006,100	1,971,400	1,971,835	1,847,915	1,870,180	1,789,200	1,822,240	1,711,460	1,663,685	1,516,115	1,368,400	1,344,030	13,085,310
Cotton	366,747	503,610	761,500	1,009,800	955,560	1,133,150	750,930	345,950	410,905	174,043	158,209	265,000	4,193,747
Beans	155,700	193,800	239,600	265,220	260,360	292,680	431,150	292,680	274,850	262,600	206,125	126,000	2,146,445
Total, Major Land Uses	18,551,527	19,236,860	21,114,195	21,974,920	25,509,223	24,821,835	25,615,970	25,768,995	25,900,715	26,578,691	26,872,573	27,454,630	208,522,632
Major Land Uses Not Including Soybeans	13,231,867	13,419,370	15,102,955	15,972,765	18,839,723	17,645,585	17,215,970	16,978,495	15,236,385	14,939,451	14,265,728	13,228,630	128,349,967
Soybeans as % of Acreage Devoted to Major Crops	29%	30%	28%	27%	26%	29%	33%	34%	41%	44%	47%	52%	38%
Double-crop Soy Hectares Planted	300,000	400,000	450,000	450,000	650,000	800,000	1,400,000	1,600,000	2,400,000	2,700,000	2,800,000	3,000,000	15,350,000
Percent of Total Soy Hectares Planed in Double-Crop Systems	6%	7%	7%	7%	10%	11%	17%	18%	23%	23%	22%	21%	19%
Soy Minus Double-crop Hectares	5,019,660	5,417,490	5,561,240	5,552,155	6,019,500	6,376,250	7,000,000	7,190,000	8,264,330	8,939,240	9,806,845	11,226,000	64,822,665
Land Newly Planted to Soy	200,000	397,830	143,750	-9,085	467,345	356,,750	623,750	190,500	1,073,830	674,910	867,605	1,419,155	5,673,845
Previous Land Use of Newly Planted Soybean Acreage													
Major Crops	80,000	170,000	80,000	-	140,000	80,000	150,000	-70,000	300,000	200,000	240,000	350,000	1,3900,000
Other Crops	30,000	60,000	10,000	-	60,000	20,000	60,000	-10,000	80,000	30,000	40,000	120,000	400,000
Alfalfa & Pasture	60,000	107,830	13,750	-49,085	107,345	36,750	133,750	-29,500	353,830	224,910	341,605	349,155	1,517,845
Forest/Savannah	30,000	60,000	40,000	40,000	160,000	220,000	280,000	300,000	340,000	220,000	246,000	600,000	2,366,000

Appendix 2. Trends in Herbicide Use in the Production of Soybeans in Argentina

Pesticide sales data are compiled annually in Argentina by CASAFE, a pesticide industry trade association affiliated with CropLife International. It is assumed in this report that the volume of pesticide sales is equivalent to the volume of pesticides applied.

Appendix Table 2 presents CASAFE data on the volume of herbicide products sold from 1999 to 2003, ranked by sales volume in 2003. (Note – the typical Argentina spelling of herbicide active ingredients as reported by CASAFE are used in this table). The enormous growth in herbicide use in Argentina in the last five years is evident.

Appendix Table 3 provides details on the volume of glyphosate (glifosato) sold from 1999-2003. The first four rows of data cover the five major glyphosate-based herbicide products sold in Argentina and report sales in litres of product at a given concentration level (48%, 74.8%, 62%, or 24%). Annual sales in kilograms of active ingredient are then reported for the five major glyphosate-based products, based on the litres sold and the concentration of the active ingredient in each litre. The row "All Glyphosate Herbicides" reports the total kilograms of glyphosate applied each year and is the sum of the volume in each of the five products in the table. Use of glyphosate has more than doubled since 1999, rising from 32 million kilograms to 67 million in 2003.

Appendix Table 3 also reports the percentage of glyphosate sales applied on soybeans versus other crops, the kilograms of glyphosate applied to soybeans, and the average rate of application per crop year (taking into account both the average application rate and the number of applications). These data are all derived in Appendix Table 4. The average rate per crop year is then used to estimate the number of hectares treated, by dividing the kilograms applied to soybeans by the average rate of application. In 2003, there were 45.9 million kilograms of glyphosate applied to soybeans at a rate of 3.25 kgs/hectare, resulting in an estimated 14.1 million hectares treated. This estimate of the total area treated is very close to the actual area planted to RR soybeans in 2003/04.

Appendix Table 4 presents estimates of the volume of glyphosate applied to soybeans in Argentina from 1995/96 through 2003/04. The first three rows report data on the number of hectares planted to RR soybeans, drawing on CASAFE and SAGPyA data discussed in section C. The volume of glyphosate applied to soybeans is then calculated by multiplying an estimate of the average rate of application in kilograms of active ingredient per hectare of soybeans, by an estimate of the average number of applications.

The estimates of the average rate of application and number of applications were extrapolated from data reported by Qaim and Traxler (2004). Their survey reported the average rate and number of applications in 2000/01 based on a survey of growers. The average rate of application was assumed to rise by about 2% per year, or by 0.02 kg/hectare, as a result of weed shifts and lessened sensitivity to glyphosate in certain weed populations. This very modest rate increase in Argentina is about one-fourth of the rate of increase in glyphosate application rates in the U.S. on RR soybeans. According to USDA data, glyphosate rates of application on RR soybeans have increased from 0.69 pounds of active ingredient per acre in 1996 to 1.04 pounds in 2002, or by about 51% over the six years, or by about 8% in a single year. Likewise, the average number of applications in Argentina was projected to gradually increase by about 5.5% per year over the seven-year period reflected in the table. The value of 2.3 applications in 1999/2000 is based on data reported in Qaim and Traxler (2004).

Given that Argentinean farmers are far more reliant on glyphosate in managing weeds in RR soybean fields than U.S. farmers, one would expect a higher rate of increase in average rates per hectare and the average number of applications in Argentina compared to the U.S. For this reason, the gradual increases in rates of application and numbers of applications in Appendix Table 2 are likely conservative.

The row "Percent Total Glyphosate Use on Soybeans" is derived by simply dividing the volume applied on soybeans in Argentina by the total volume sold as reported by CASAFE.

Appendix Table 2. Herbicide Sales Volume in Litres of Formulated Product from 1999 to 2003 in Argentina Ranked by 2003 Sales

Active Ingredient	Concentration	Principle Crops	1999	2000	2001	2002	2003	Percent Change 1999 to 2003
GLIFOSATO	48%	Soybeans	60,974,464	82,364,2000	81,499,870	78,337,685	110,913,525	81.9%
GLIFOSATO	74.8%	Soybeans	3,500,000	5,000,000	6,600,000	13,800,000	17,300,000	394.3%
ATRIZINA	50%	Corn	4,946,409	8,374,000	7,263,724	7,119,960	8,252,220	66.8%
2,4-D ESTER	100%	Soybeans, Corn	3,464,410	4,139,827	4,759,759	3,811,607	5,239,645	51.2%
ACETOCLOR	90%	Corn	2,251,193	1,775,000	1,686,928	1.781,988	2,501,159	11.1%
ACETACLOR + ANTIDOTO	84%	Corn	1,466,634	1,200,000	1,239,200	1,152,367	2,130,770	45.3%
S-METOLACLORO + ATRAZINA	96% +90%	Corn		650,000	600,000	624,145	1,456,000	
GLIFOSATO + IMAZETAPIR	24% + 2%	Soybeans	1,000,000	750,000		450,160	1,315,000	31.5%
GLIFOSATO	62%	Soybeans	0	900,000		133,140	984,500	

Appendix Table 3. Glyphosate Sales in Argentina, 1999 to 2003 (litres of formulated product and kilograms of active ingredient)							
Active Ingredient	**Concentration**	**1999**	**2000**	**2001**	**2002**	**2003**	**Percent Change 1999 to 2003**
Sales in Litres							
Glyphosate	48%	60,974,464	82,364,200	81,499,870	78,337,685	110,913,525	81.9%
Glyphosate	74.8%	3,500,000	5,000,000	6,600,000	13,800,000	17,300,000	394.3%
Glyphosate	62%	0	900,000		133,140	984,500	
Glyphosate + Imazetapir	24% + 2%	1,000,000	750,000		450.160	1,315,000	31.5%
Sales in Kilograms Active Ingredient	**kilograms per litre**	**1999**	**2000**	**2001**	**2002**	**2003**	**Percent Change 1999 to 2003**
Glyphosate	0.48	29,267,743	39,534,816	39,119,938	37,602,089	53,238,492	81.9%
Glyphosate	0.748	2,618,000	3,740,000	4,936,800	10,322,400	12,940,400	394.3%
Glyphosate	0.62	-	558,000	-	82,547	610,390	
Glyphosate + Imazetapir	0.24	240,000	180,000	-	108,038	315,600	31.5%
All Glyphosate Herbicides		32,125,743	44,012,816	44,056,738	48,115,074	67,104,882	108.9%
Percent Glyphosate Applied to Soybeans		58.2%	61.8%	74.6%	77.2%	68.4%	17.4%
Kilograms Applied to Soybeans		18,696,552	27,167,626	32,858,130	37,124,468	45,867,961	145.3%
Average Rate per Crop Year (kg/hectare)		2.76	2.83	2.90	2.97	3.25	17.8%
Hectares Treated		6,774,113	9,598,511	11,324,142	12,484,688	14,113,219	108.3%

Appendix 4. Changes in Herbicide Use Triggered by the Expansion of No-till and Roundup Ready Soybeans in Argentina, 1995 to 2004											
	1995 - 1996	**1996 - 1997**	**1997 - 1998**	**1998 - 1999**	**1999 - 2000**	**2000 - 2001**	**2001 - 2002**	**2002 - 2003**	**2003 - 2004***	**Totals 1995 to 2003/04**	**Percent Change 1996/97 to 2003/04**
Area Planted											
Soybeans Planted (million Hectares)	6.002	6.670	7.176	8.400	8.791	10.664	11.639	12.607	14.226	86	113.3%
Percent Hectares Planted to RR Soybeans	0%	6%	25%	59%	77%	90%	97.3%	99%	99.2%	71.3%	1,533.3%
Million Hectares Planted to RR Soybeans	0	0.4	1.794	4.956	6.679	9.598	11.325	12.481	14.112	61	3,426.5%
Glyphosate Applied											
Average Rate of Glyphosate Application (kg/hectare)		1.14	1.16	1.18	1.2	1.22	1.24	1.26	1.3		14.0%
Average Number of Applications		1.8	1.9	2.0	2.3	2.32	2.3	2.36	2.5		38.9%
Million kgs of Glyphosate Applied to All Crops*	4.02	6.67	15.06	24.04	32.10	44.01	44.06	48.10	67.10	285	906.2%
Million kgs of Glyphosate Applied to Soybeans	0	0.82	3.95	11.70	18.68	27.17	32.86	37.11	45.86	178	5,485.4%
Percent Total Glyphosate Use on Soybeans	0	12.3%	26.3%	48.7%	58.2%	61.7%	74.6%	77.2%	68.4%	62.5%	
Other Herbicides on RR Hectares											
Percent Soybean Acres Treated	0	2%	4%	6%	10%	18%	28%	35%	45%		2,150%
Average Rate of Application (kg/hectare	0.00	0.3	0.35	0.4	0.4	0.45	0.5	0.6	0.65		116.7%
Million kgs of Other Herbicides Applied	0	0.002	0.03	0.12	0.27	0.78	1.59	2.62	4.13	9.5	171,819.3%
All Herbicides on RR Hectares											
Million kgs of Herbicide Applied to Soybeans	0	0.8	4.0	11.8	19.0	27.9	34.4	39.7	50.0	188	5,970.4%

* kgs of glyphosate for 1999-2003 are calculated from CASAFE data on all glyphosate-based herbicides. Values for 1995-98 are based on CASAFE data on 48% glyphosate multiplied by 1.1, based on the assumption that glyphosate products other than 48% concentrate accounted for 10% additional volume of sales.