Transgenic Crops in Argentina: The Ecological and Social Debt

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There is no doubt that soybean is the most important crop for Argentina, with a planted surface that rose 11,000,000 hectares and a production of around 35,000,000 metric tons. During the 1990s, there was a significant agriculture transformation in the country, motorize by the adoption of transgenic crops (soybean, maize, and cotton) under the no-tillage system. The expansion of this model has been spread not only in the Pampas but also in very rich areas with high biodiversity, opening a new agricultural border to important eco-regions like the Yungas, Great Chaco, and the Mesopotamian Forest. Transgenic cropping is a powerful technology. This produced relevant transformations over the environment and society where it is allowed. Migration, concentration of agribusiness, and loss of food sovereignty are some of the social results. Landscape transformation in the rural sector is evident, and the appearance of tolerance weeds to glyphosate is a reality. Nutrient depletion, soil-structure degradation, potential desertification, and loss of species are other consequences on the environmental level.

Keywords: *transgenic crops; soybean; nutrient extraction; Argentina; Pampas; ecological debt*

Soybean has become the most important crop of Argentina as a direct consequence of globalization in commodity trade, an open market, and a strong campaign on technological changes. For the farmers, Roundup Ready soybean came up as a solution for one of the main problems in farm management, namely, weed control. Cost reduction in the herbicide price, less fossil energy consumption, and simple application methods made the offer of the technical package very attractive. For the private pesticide- and seed-production sector, it opened a unique possibility to concentrate and rearrange the business of production and commercialization of insecticides and herbicides to the new biotechnological alternative.

The rising ecological and social debt that has emerged due to this technology has not detained the expansion, and instead, an important portion of the country is being transformed into a cluster of productive commodities, especially soybean grain, cake, and oils. The expansion of this model has spread not only in the Pampas but also in areas rich in biodiversity, opening a new agricultural frontier in important ecoregions like the Yungas, Great Chaco, and the Mesopotamian Forest.

Landscape transformation in the rural sector is evident, and the appearance of glyphosate-tolerant weeds is becoming a common occurrence. Nutrient depletion, soil-structure degradation, potential desertification, and loss of species are some of the results of the overexploitation associated with the monoculture production of the genetically modified (GM) soybean. Migration from rural areas, concentration of agribusiness, and loss of food diversity and food sovereignty are some of the consequences at the socioeconomic level.

Other countries such as Brazil, Bolivia, Paraguay, and Uruguay are at this time facing a similar of expansion of transgenic crops for extensive production and agro-exports. *Hidrovia Paraguay-Paraná* is the waterway for this production that passes through landscapes characterized by extensive floodplain wetlands and a complex set of different ecosystems.

Soybean Production in Argentina

Soybean production became a relevant crop for Argentina, with a planted surface that has been quickly rising since the 1990s (Figure 1) and that, in the last

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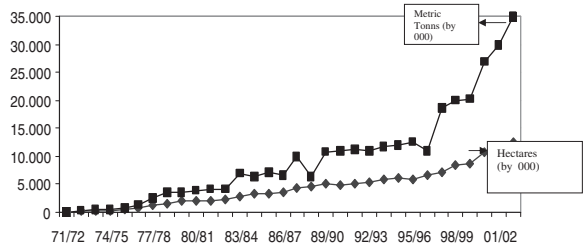

Figure 1. Soybean Production in Argentina and Area Planted

Source: Secretaria de Agricultura, Ganaderia, Pesca y Alimentación (http://www.sagpya.mecon.gov.ar).

Note: The figures for soybean production are in thousands of metric tons and those fore area planted are in thousand of hectares. During the 1990s, there was a significant agricultural transformation in the country, fueled by the adoption of transgenic crops (soybean, maize, and cotton) and the associated no-tillage systems.

campaign, reached an area of 12,100,000 hectares and a production of around 35,000,000 metric tons.

Argentina is the world's largest exporter of soybean cake, followed by Brazil (Table 1). The importing countries are primarily European countries, such as Spain, Italy, the Netherlands, and Denmark (Figure 2).

The Expansion of the Agricultural Frontier

At first, soybeans were mainly produced at the Pampas, which is one of the most productive places in the world. But currently, due to the need for larger-scale production, farmers are expanding the area and increasing the pressure on more environmentally sensitive areas such as the rain forest of Yungas or the Chaco (Figure 3). The situation is the same in the marginal areas within different ecoregions in other neighboring countries such as Bolivia, Brazil, and Paraguay.

Table 1. The World's Major Commodity Exporters in 2002 Ranked According to Value in U.S. Dollars

Ranking	Country	Commodity	Value (000)
1	United States	Soybeans	5,623,574
2	France	Wine	5,397,735
3	United States	Maize	5,127,628
12	Argentina	Soybean cake	2,561,391
13	Australia	Wheat	2,249,551
14	Brazil	Soybean cake	2,198,860
15	Denmark	Pig meat	2,191,785

Source: Food and Agricultural Organization (2004b).

Note: The major exporters of soybean cake are Argentina and Brazil, and Denmark is the major exporter of pig meat.

The Pampas prairie is a vast, flat region of Argentina that comprises more than 50,000,000 hectares of excellent arable lands for crop and cattle production. Agriculture in the Pampas has a short history (100 years) and shares several common features with the agricultural history of the North American Great Plains. Both ecoregions were mostly native rangelands until the end of the 19th century, and both of them were later transformed for crop and cattle production on dryland conditions.

The Pampas prairie is not homogeneous in soil, weather, or biodiversity patterns (Morello & Matteucci, 1997). Using soil and rainfall patterns, the Pampas can be divided (Viglizzo, Pordomingo, Castro, & Lértora, 2002) into five homogeneous areas: (a) Rolling Pampas, (b) Central Pampas (subdivided in subhumid in the East and semiarid in the West), (c) Flooding Pampas, (d) Southern Pampas, and (e) Mesopotamian Pampas. It is in these areas that transgenic soybean and no-till agriculture started to spread as farmers strongly adapted them (Pengue, 1999).

In Argentina, especially in the Pampas, soybean production has, in the last 5 years, displaced 4,600,000 hectares of land dedicated to other production systems such as dairy, fruit trees, horticulture, cattle, and some grain. This year, more than 50% of the whole production of the agrifood sector (73,000,000 metric tons) in Argentina comes from the soybean sector. The impact

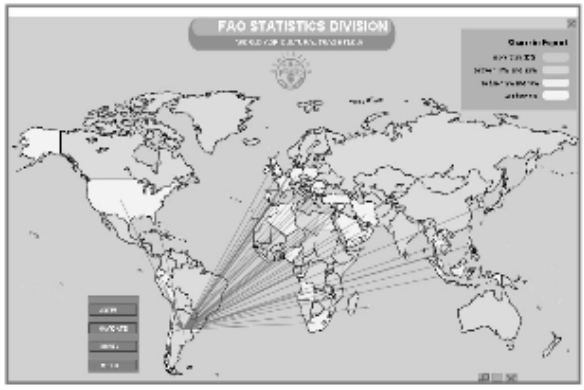

Figure 2. Export of Soybean Cake from Argentina in 2002 (16,172,000 metric tons)

Source: Food and Agricultural Organization (2004a).

Note: The lines show the export flows of soybean cake to different countries where Spain, Italy, the Netherlands, Denmark, and Egypt are the major importers.

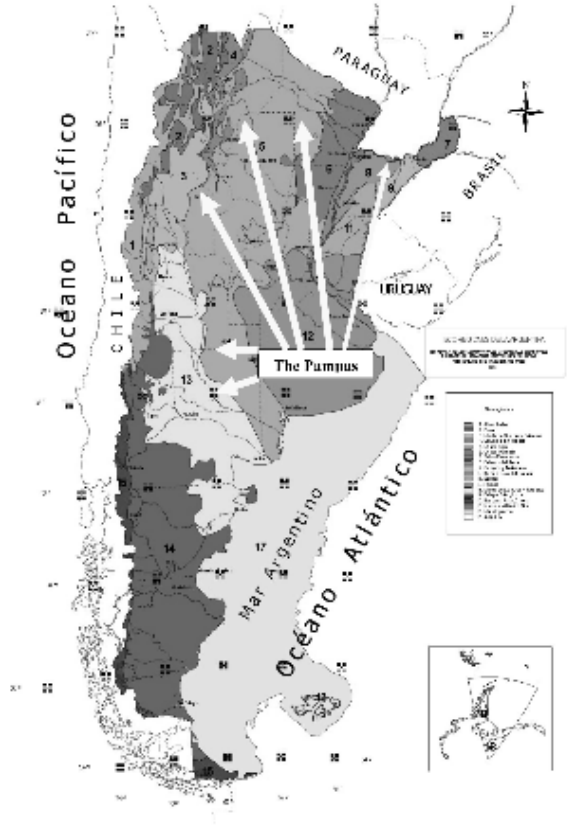

Figure 3. The Pampas and the Ecoregions of Argentina: Expansion of the Transgenic Model

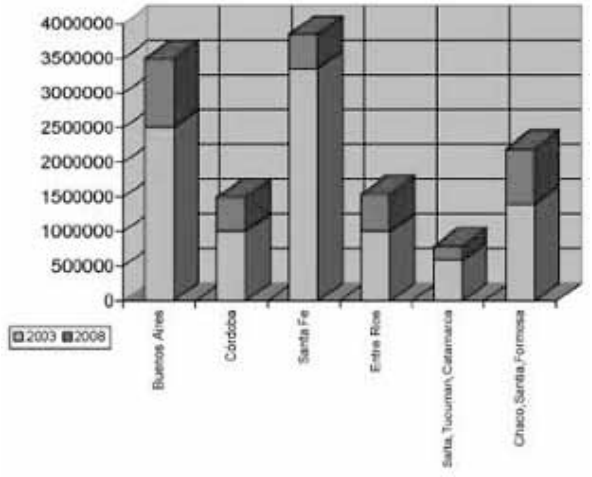

Figure 4. Soybean Expansion: New Cropping Lands Expected to Be Added During Next Years

Note: In green: surface planted during 2003 to 2004 season; in red: new surface to be added in different ecoregions.

of such displacement on food security is now starting to be felt, and it is expected to worsen as the private sector and the government have made it a goal to increase soybean production to "100 hundred million metric tons." This expansion will definitely impact the ecological integrity of marginal areas, which still exhibit around 90% forest cover (Figure 4).

During the past years, the advances of soybean into natural areas in Argentina seem to have no limits. Forest areas and marginal lands are facing the advances of the agricultural frontier. Environmental transformations are more intensive in the northwest and east of Argentina. Some states of the country have lost to intensive agriculture more than 50% of the native lands that they had in 1935. It is expected than in the period from 2003 to 2008, soybean acreage will increase from 12,100,000 planted hectares to 16,000,000 hectares, with an estimated production of 44,000,000 metric tons of soybean. An important part of these hectares will be new land, which implies deforestation and loss of biodiversity.

Phosphorous Export and Depletion of Argentinean Soils: Increasing the Ecological Debt

The increase in the soybean sector in the 1990s and the increase in fertilizer use drove the Argentinean Pampas into a more intensive agriculture that is more typical of the Northern than the Southern Hemisphere. Such intensification of the soybean production system has been accompanied by a decline in soil fertility and an increase of soil erosion (Prego et al., 1997). Consequently, the fertilizer consumption stepped up from 300,000 metric tons in 1990 to 2,500,000 tons in 1999. In most of Argentina, soybean has been cropped without fertilization, although soil phosphorus contents have decreased. Areas earlier considered to be well supplied are at present phosphorus deficient (Scheiner, Lavado, & Alvarez, 1996). The demand for phosphorous and the depletion of natural reposition are particularly important in the Pampas, where phosphorus extraction has been increasing during the past decade.

Two decades ago, the nutrient budgets of the Pampas were relatively stable, due to the use of crop and cattle rotation, which allowed nutrient recycling. Each year, the country exports a considerable amount of

nutrients with its grains—especially nitrogen, phosphorus, and potassium—that are not replenished, except from the nitrogen that is derived from atmospheric fixation. Argentina exports yearly around 3,500,000 metric tons of nutrients—obviously not reflected in the market prices, thus increasing the "ecological debt" (Martinez Alier & Oliveras, 2003). Soybean, the engine of this transformation, accounts for 50% of this value. If the natural depletion were compensated with mineral fertilizers, Argentina would need around 1,100,000 metric tons of phosphorous fertilizers at a cost of US$330,000,000 in the international market (Pengue, 2003). Estimates for 2002 showed that around 30% of the whole soybean area (4,500,000 hectares) was fertilized with mineral fertilizers. Ventimiglia (2003) predicts that nutrients of Argentinean soils will be totally consumed in 50 years at the current rates of nutrient depletion and an increase of soybean area.

Soybean has had and will continue to have an emblematic role in relation with the loss of quality of Argentinean soils and, in marginal areas, with the trends in deforestation (Pengue, 2004a).

New Technologies and Socioeconomic Transformations

Imported new technologies, short-term economic success of the no-tillage system, transgenic soybeans, and an exploding application of very specific pesticides resulted in a particular situation that duplicated the Argentine production during the past decade, which may be called the "Input Decade." Since 1997, private companies, in many cases with the support of the governmental sector, offer a transgenic package (soybean + glyphosate) that according to biotech promoters, provides farmers and the country a "real competitive advantage" (Pengue, 2000).

Due to this and other natural and structural advantages, Argentina became one of the "most efficient" (under an agricultural and chrematistic point of view) countries for producing and trading agricultural commodities. Since the 1996 to 1997 season, there has been a strong campaign for the commercialization of transgenic soybeans, resulting in an increase of the genetically engineered (GE) soy acreage from 20% to 95% of the total soy acreage in 2003 to 2004. Argentina did not generate the new technology; it belongs to and was brought into the country by international companies like Monsanto (United States) and Nidera (the Netherlands).

In the past, traditional grain cultivation was combined with fallow seasons to grow cattle pasture. This rotation system allowed the long-term maintenance of agronomic and environmental systems. But since the 1980s, world market prices for grains and oilseeds increased, while productivity of cattle declined. Intensive and continuous cultivation became more lucrative, for example, the production of soybeans in rotation with wheat or sunflower that allows three harvests in 2 years (Pengue, 2000). Furthermore, the opening of the Argentina economy to the global market, the end of hyperinflation due to the fixation of the Argentine peso with the U.S. dollar, and the abolition of export levies on agricultural products triggered investments in new technologies. This new framework favored the import of machinery and agricultural inputs as pesticides, fertilizers, and intellectual-property-rights–protected seeds at low prices and their use in oilseed production under a no-till system for export markets. At the beginning of the 21st century, a new devaluation and important signals from the global market indicating rising soybean prices strongly encouraged soybean production.

The main factors associated with the rapid adoption of the transgenic soybean and no-till package can be summarized as follows:

a. Lower herbicide prices. In Argentina, glyphosate price of $28/liter went down to $3/liter, much cheaper than in the United States. Four companies (Monsanto, Atanor, Nidera, and Dow) control more than 80% of the glyphosate market in Argentina, which is mainly imported from the United States, the European Union, and China (Lehmann & Pengue, 2000).
b. Access to new imported machinery, fertilizers, and pesticides, especially since the beginning of the 1990s when Argentina opened its economy.
c. A strong campaign of private-sector, government, large farmers, corporations, and scientific and academic organizations that promoted the package among farmers.
d. Fewer expenses on labor, fuel, and machinery. Direct sowing and more-effective herbicide application allow for crop cultivation with less labor and machinery and, consequently, a reduction in production costs.
e. Increased awareness by farmers that the technological package no-till system + GE Soybean facilitates weed management.

f. Seed prices and self-reproduction. In Argentina, farmers do not pay technology fees for seeds as farmers do in United States. They can reproduce the new seeds in their fields. Argentina signed the International Union for the Protection of New Varieties of Plant Agreement 78, so farmers can plant their own seed. This is one reason for agribusiness companies to put pressure on the government to restrict the soybean-seed trade (Ordoñez, 2004).

The true result of the expansion of this technological model in Argentina and in South America is the intensification of agriculture that takes advantage of the extensive lands available in many of the Southern Cone countries. As a result, there has been a deep transformation of land use:

1. Intensification of production with high-input technology on existing agricultural land in the most of the Pampas and other agro-environments.
2. Extensive production on new lands, pushing forward the agricultural frontier with new varieties of soybeans, bred specifically to be adapted to such lands. This process is very pronounced in Brazil (Mato Grosso, Paraná, Santa Catarina, Rio Grande do Sul, and others states), Bolivia (Santa Cruz de la Sierra, Beni), Paraguay, and Argentina (Chaco, Formosa, Salta, Tucumán, Jujuy, and Santiago del Estero).
3. An intensive movement for agricultural commodities via river transportation. Probably *Hidrovía Paraguay Paraná* could accelerate the expansion of soybean production and facilitate the process of agro-export downstream.

Agriculture intensification has produced environmental, economical, and social consequences that have not been evaluated comprehensively in the country. Probably, the new biorevolution could exacerbate many of the problems associated with the dominant agricultural systems: intensification of agriculture, globalization, large farm concentration, low levels of credit for small farmers and for diversification, dependence on imported inputs and technology, appropriation of large farms by foreign owners (around 16,600,000 hectares have been sold to foreign companies), and concentration of the seed and chemical business in the hands of a few agricultural firms.

Soybean monoculture has also produced effects that can affect the commercial position of Argentina by emphasizing large farms exclusively producing commodities with high yielding crops instead of more natural foods that are also demanded by the global market (agro-ecological systems for organic farming).

There are social and economic consequences stemming from agriculturally induced changes and transformations of the national economy. Since 1991, when the period of dollar convertibility opened the Argentine market, changes in the mode of production have led to a number of social transformations in the agricultural sector:

a. Dependence on imports. Grains and soybean have become the main commodities for foreign markets, boosting the dependence on imported inputs. Local production of pesticides is 16.6%, whereas 43.6% is imported and the other 39.8% is produced in Argentina with imported basic chemicals. A similar pattern is true for fertilizers.
b. Concentration of holdings. The new technological package is offered in a context of profit margins falling down by 50% between 1992 and 1999, which made the survival of many farmers very difficult. Farmers are indebted with bank loans linked to high interest rates to pay back for investments in machinery, chemical inputs, and seeds. This situation favors the establishment of large holdings and the disappearance of smaller farmers (14,000,000 hectares are in debt with loans by banks and big companies). Between 1992 and 1999, the number of farms in the Pampas declined from 170,000 to 116,000, while the average size of farms increased from 243 to 538 hectares in 2003 (Table 2).
c. Loss of land devoted to food crops (fruits, dairy, cattle, maize, wheat, sunflower, cotton, sugarcane, etc.). In a decade, the soybean acreage increased by 126%. During the season from 2003 to 2004, 13,750,000 hectares had been planted (9.1% more than the previous season). Sunflower area was reduced by 9.6% (2,150,000 hectares) and maize by 5.6% (2,910,000 hectares).
d. Dumping prices of develop countries. These practices further promote the intensification of agriculture production in developing countries, overexploitation of resources, and

Table 2. Reduction of Number of Agricultural Farms in Argentina by Region

Year	Total	Pampas	NEA	NOA	Cuyo	Patagonia
1988	421,221	196,254	85,249	72,183	46,222	21,313
2002	317,816	136,345	68,332	63,848	32,541	16,750
Difference %	–24.5	–30.5	–19.8	–11.5	–29.6	–21.4

Source: Based on data from the National Institute of Statistics and Censuses (2002).
Note: NEA = Northeast Argentina; NOA = Northwest Argentina.

subutilization of alternative goods (it is not included in the evaluation of externalities).

e. Argentina cannot export goods with added values. From a total production of 70,000,000 metric tons, only 2% will be products with other values after being processed in the agrifood chain because of the effects of protective systems in the importing countries.
f. Exclusion of small farmers unable to get financial support for the acquisition of the technological package.
g. Adverse consequences of GE crops for organic farming by contamination via gene flow.
h. Each person in Argentina currently eats 10kg less meat than in the year before. The alternative for poor people, promoted by companies, is to change the diet to include more soybeans: a substantial cultural transformation. A similar trend to eat lower-quality protein (from meat, eggs, and milk) favoring instead soybean protein occurs in other South American countries. We are facing a battle for high-quality protein between developed and developing countries.

The data above lead to the conclusion that short-term economic objectives ignoring mid- and long-term socioeconomic and environmental effects threatened the future sustainability of agriculture in Argentina and placed society at risk. However, although indicators to measure social or economic changes are abundant, indicators for assessing environmental changes associates with transgenic farming are scarce. The generation and development of proper indicators for creating an agro-environmental information system is essential to enable a permanent quality assessment of rural environments.

Environmental Considerations

In the Pampas, the application of the technological package transgenic soybean + glyphosate caused the appearance of the first glyphosate-tolerant weeds: *Parietaria debilis*, *Petunia axilaris*, *Verbena litoralis*, *Verbena bonariensis*, *Hybanthus parviflorus*, *Iresine diffusa*, *Commelina erecta*, and *Ipomoea sp.* (Papa, 2000). Some of these weed species need increased dosages of commercial application of glyphosate to be controlled (Figures 5 and 6).

Figure 5. ***Commelina erecta***

This implies a further increase in the application of herbicides (Figure 7). The change of the herbicide regime already led to a tremendous increase on glyphosate consumption from 1,000,000 L to 160,000,000 L in 2004. Furthermore, farmers are starting to use combinations of glyphosate with other herbicides, reestablishing the use of the old herbicide 2.4-D to deal with difficult-to-control weeds.

Coadjutants and surfactants are organic compounds used to increase the adsorption of glyphosate into the plant leaves. Some commercial products contain the surfactant polyoxyethyleneamine, or POEA, which

Figure 6. *Ipomoea sp.*

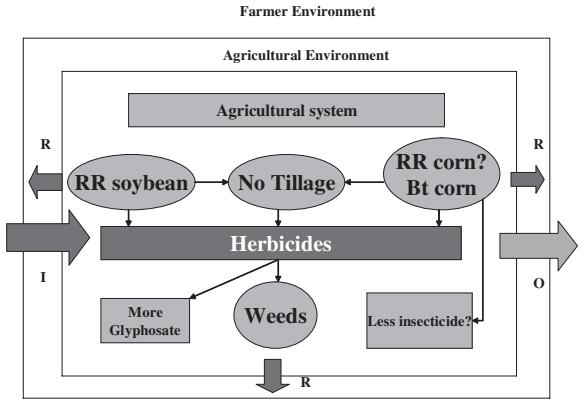

Figure 7. Simplification of the Agronomic Management Under Roundup Ready Soybean and No-Tillage System

Source: Pengue (2001).

Note: I = Input; O = Output; R = Resistance or Tolerance.

exhibits a toxicity 5 times higher than that of glyphosate. The expansion of the cropping area and the more-intensive use of pesticides over time show a strong increase of the overall relative contamination risk.

Another environmental indicator that relates to agriculture is the intensification in land use. Land use is the most important factor that determines the environmental status of a region. All indicators, from fossil-energy consumption to contamination risk, from erosion risk to greenhouse-gas emission, are particularly sensitive to land use (Viglizzo et al., 2002).

Trends in fossil-energy consumption in the Pampas indicate that intensification is increasing at high rates. Land productivity and fossil-energy consumption have almost doubled in less than 10 years.

In general, the Pampas were not fertilized until the beginning of the 1990s. The nutrient budget had been equilibrated by the rotation of crops and cattle. But, in the 1990s, things changed dramatically, and along with its grains, the country began exporting a considerable amount of nutrients each year—especially nitrogen, phosphorus, and potassium. Argentina exports around 3,500,000 metric tons of nutrients yearly. Intensification does not allow for a process of natural replenishment to occur (Martinez Alier, 2003; Martinez Alier & Oliveras, 2003; Pengue, 2004b). Soybean, the engine of this transformation, represents around 50% of the average nutrient export (Table 3; Pengue, 2003).

Estimation for the season from 2003 to 2004 showed that about 30% of the whole soybean area (4,500,000 hectares) was fertilized with mineral fertilizers. This shows a trend toward substantial depletion of nutrients in Argentinean soils, and if the trend continues, nutrients will be totally extracted in 50 years (Ventimiglia, 2003). This will occur despite the fact that under no-till, agriculture indicators show that soil-erosion risk declines.

Aggressive agronomic practices, global demand for soybean, and attractive prices without appropriate national regulations and economic instruments encourage the negative impact of intensive land used on natural habitats and biodiversity. Argentina is a country in South America that established only few protected areas (4.8% of the total land as opposed to other countries such as Brazil with 16.8%, Bolivia with 22.4%, and Peru with 9.9%; Burkart, 1999). In very few years, thousands of hectares of virgin lands have been transformed at an accelerating rate: Between 1998 and 2002, deforestation affected 117,974 hectares in Chaco State, 160,000 hectares in Salta, and 223,000 hectares in Santiago del Estero (Montenegro, Strada, Parmuchi, Gasparri, & Bono, 2004).

Some Final Comments

The model of intensification of the Argentine agriculture, represented by the use of the no-till system and glyphosate, has resulted in the homogenization of production and landscapes based on transgenic soybeans as the dominant crop.

Table 3. Estimation of Nutrients Exportation and the Reposition Cost for the 2002-2003 Soybean Harvest (34,000,000 Metric Tons)

	Nitrogen	Phosphorus	Total
Nutrient extraction (metric tons)	1,020,000	227,800	1,247,800
Equivalent in mineral fertilizers (metric tons)	2,217,400	1,109,386	3,326,786
Cost stimulation reposition (US$)	576,524,000	332,816,000	909,340,000

Source: Pengue (2003).

The present, export-oriented, commodity-production system is most likely to drive smaller farmers that are not able to face uneven competition out of business. For them, a diversification beyond global commodity markets with other crops for internal market purposes might render an alternative development trajectory.

The overwhelming dependence on transgenic soybeans makes farmers and the country especially vulnerable to changes in the global commodity markets. Argentina is efficient in terms of soybean production, but monoculture exacerbates dependence. Soybean intensification has produced social and economic consequences. Thousands of small- and medium-scale farmers have been forced out of the production system. In 10 years, the country lost its food sovereignty by concentrating on a few commodities for agro-export without an added value. Poor people cannot afford a diverse diet any more. The protein basis of their meals was changed from high-quality meat proteins to soy protein. Of Argentine children (2,108,237), 20% show signs of undernourishment.

The 1990s were characterized by a transition toward a more intensive model of agricultural production, in terms of both land use and technology application. Many farming systems in Argentina resemble some intensive models that are very common in the United States or Europe and that exhibit similar environmental problems.

Nutrient depletion is a new, complex issue that must be solved with holistic agro-ecological methods and policies, not with the current approach of increasing the application of mineral fertilizers. Overexploitation of natural resources and subutilization of alternative goods (by not incorporating externalities in the cost of production) are increasing the ecological debt.

Deforestation and expansion of agricultural frontiers must be stopped, and new political decisions are needed to avoid an important loss of biodiversity and natural habitats. Indicators showing negative environmental or social trends are important keys to identify critical problems that will require more urgent attention by researchers and government. The increase of genetic pollution risks, increased use of fertilizers, biodiversity loss, and monoproduction must be broadly discussed to assure strategies that will protect the future sustainability of the Pampas and the environment of the whole country.

South American countries are using a very important "subsidy": their own environment. Some short-term economic gains resulted, but intensification of the process has negatively affected some people and different environments. If the tools of ecological economics are applied by incorporating the externalities, agricultural outcomes would be very different.

There is an increasing consensus among consumers that they want safe, local, organic fresh food and that they want the environment and wildlife to be protected. Assuring that these things happen, South American countries must proceed with a broader evaluation of their agricultural policies and practices using the Precautionary Principle.

But changes of the current situation depend not only on the definitions of new rules in the Agricultural and Environmental National Policy but also on the existing demand of global customers and rich countries that should value and pay properly for agro-ecological goods coming from developing countries. It is clear that this will require substantial changes in the Global Agricultural Policy.

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