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Agrofuels and Agrifoods

Counting the Externalities at the Major Crossroads of the 21st Century

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The economically successful model of industrial agriculture that is currently expanding throughout Argentina is leading to deep social, economic, environmental, and logistical changes that are seriously restricting the sustainability of the rural, urban and environmental systems. The transformation of activities, the arrival of new technologies, the arrival of organizations with large financial and technological capabilities, the displacement of hundreds of thousands of small-scale and medium-scale farmers and their reallocation to new productive functions are not only affecting the social sustainability of the rural sector but are affecting the urban communal plots of villages and towns located on the Chacopampeana Plain. Now, the production of agrofuels as a response to international global demand will promote the ecological and social depletion that Argentina has been facing from the beginning of the 1990s. We argue in terms of ecological economics that externalities should be included in the costs of companies, not just economic costs.

Keywords: *agrofuels; soybean; transgenic crops; externalities; ecological economics*

An Intensification of the Agricultural Model and the Demand for Agrofuels

Argentina has nearly tripled its agricultural production, but it has also lost, at the same rate, farmers and the best of its natural environment. There are two main factors that promote the expansion of soybean and corn production: grain and meal for the global market to feed animals (pigs and fishes) and the new demand for biofuel exportation.

Soybean production has increased at an unprecedented rate, with cultivation increasing from an area of 38,000 hectares in 1970 to more than 16 million hectares today (Figure 1). Around 70% of the soybean harvested is converted in oil-processing plants, most of which is exported, providing 81% of the world's exported soybean oil and 36% of soybean meal.

The total cultivated area in Argentina is four times the area cultivated with corn, and trends show that soybean and corn cultivation will increase, displacing other crops such as sunflower and sorghum, in the main rural area of production in Argentina, the Pampas.

The extent of crop displacement is alarming. If we compare the last 10 years of production of the main summer crops (sorghum, corn, sunflower, cotton, rice, and soybean) between 1995/1996 and through 2007/2008, the area of sorghum cultivation increased by 159,320 hectares and corn by 597,450 hectares, whereas sunflower, cotton, and rice production decreased by 750,600, 679,800, and 27,400 hectares, respectively. Soybean production increased by 10,597,845 hectares from 1996/1997 to 2007/2008. In 1996, the first transgenic crop, RR soybean, was released. In 2008, all the soybean produced in Argentina was transgenic.

Increase in agrofuel[1] production has been rising during the last 10 years at a high rate, associated with the increasing production of soybean. Argentina has a framework that regulates and promotes the production and use of agrofuels since 2007 (Carballo, Marco, Anschau, & Hilbert, 2008). The law mandates the use of agrofuels by 2010, with an obligatory mix of 5% of ethanol in gasoline and 5% of biodiesel in diesel. To comply with the biofuels law (No. 26093), it is estimated that a volume of about 700 million liters of biodiesel and 250 million liters of ethanol will be needed (Carballo et al., 2008). This leads to a demand of 717,000 m^2 for internal consumption, which leads to an increase in soybean production area of 1,400,000. This is around 9% of the seeded soy area in the country for the year 2007/2008. For the first year of implementation

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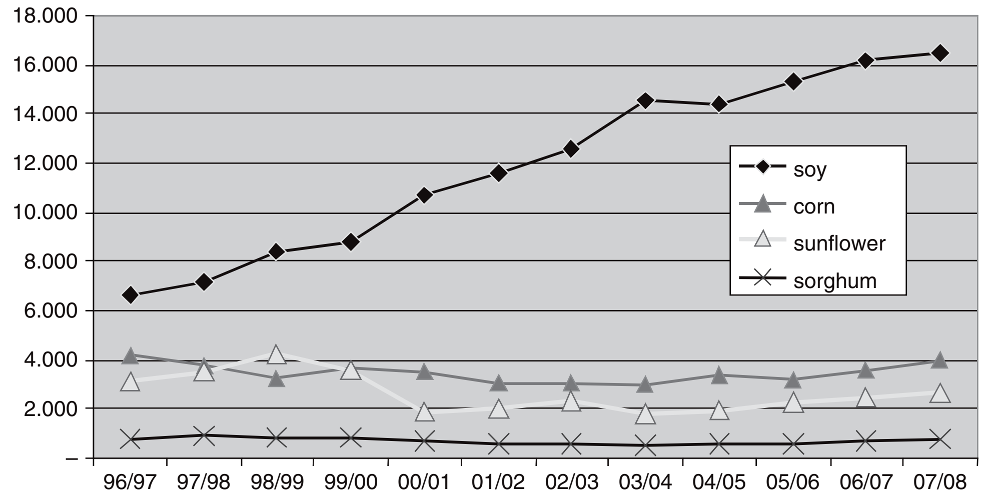
Figure 1
Evolution of Cultivated Area (hectares × 1000) in Argentina



of the law alone, Argentina will need 100,000 tons of biodiesel, which represents 3,500,000 metric tons of soybean (9%). To obtain 152,000 tons of bioethanol, 106,000 hectares of corn (3.2% of the current area) and 550,000 metric tons of soybean (2.8%) will be needed.

Agrofuels are a new important component of agroindustrial intensification. Argentina is facing a revolution in terms of technological adoption. The arrival of no tillage systems with transgenic crops that support the application of herbicides means that more soybean can be planted (Dalgaard et al., 2007), and this is promoted to an unimaginable extent by the international market.

The combination of these two techniques has increased the level of intensive farming for export. The main aim has been to compete in the agricultural world market. This is not an easy task as the market is often distorted by the agricultural subsidies received in many countries.

But now, while we are still struggling to manage this uneven growth, the country faces a new, more powerful dilemma: The supply of raw materials has to be further increased, stretching the rural borders largely beyond any rational limit. The demand for bioenergy has affected the food and energy scene on global and regional scales, and it has a strong economic thrust. This is likely to lead to a situation where millions of tons of food will be used to support the unsustainable energy voracity of overdeveloped economies, thus, fueling the global inequality that already exists among much of humankind.

In the year 2007, 300,000 metric tons of biodiesel were exported from Argentina, of which 75% went to the United States and 25% directly to the European Union. In the beginning of 2008, there were eight companies exporting biodiesel, with a production capacity of around 600,000 tons per year. In 2008, seven more plants started operations. For the beginning of 2009, the estimate for biodiesel production is around 1.1 millions tons.

Deciding whether to inject our food into the fuel tanks of 800 million vehicles or whether to make it more accessible to the starved stomachs of 2 billion human beings is not a minor question. It is not an economic question nor even a technological one. It is merely an ethical question, which neither the global society nor governments are examining in the calm and fair manner that it merits.

Biomass is a very interesting alternative for the production of fuel, but it does not come from crops. Biomass can come from residues in the urban and rural sector, wood industry, food industry, and other sources. To date, the world is not really prepared to produce energy from crops, unless the environmental and social considerations of this decision can be ignored. Sugarcane is currently the main feedstock for ethanol production in Argentina (Hoff, 2007). Besides this, there is also an interest in the use of sorghum for ethanol production. There exist around 15 to 16 small-scale producers of bioethanol who serve the beverage, food, and pharmaceutical industries. Project BIOFAA[2] has been designed to assist small- and medium-scale farmers who wish to produce their own fuel from rape seed oil or soybean.

Externalities of Agrofuel Demand

There are many negative externalities (also called external costs or external diseconomies) related to the

Table 1
Externalities

Social cost = Private cost + Externality

environmental consequences of production and use of natural resources such as overexploitation, destruction of habitats, or accumulation of contaminants that affect the environment and society.

These are direct costs that are not recognized by the private sector but that affect the whole society. Externalities must be incorporated into the private cost of the companies (Table 1), but if they are, the cost of production would be more than the incomes of these companies. As a result, externalities are not being implemented in the current model of agriculture, and the results of this failure are well known: the overexploitation of pristine nature, and contamination and degradation of the agroecosystems of the world.

Environmental economics (Pearce, 1976; Turner, Pearce, & Bateman, 1993) is the study of ways of incorporating externalities in the costs of companies, and David Pearce and other economists have been promoting this for decades. But all of this has been done under using a monocriterial method of analysis—namely, a chrematistic analysis. Ecological economics (Costanza, Cumberland, Daly, Goodland, & Norgaard, 1997) takes into account this condition but expands the focus of the different ways of valuation, so that they include not only economic considerations but also take into account other issues such as social metabolism and biophysical indicators (nutrients, virtual water,[3] HANPP[4]), trends in energy consumption, natural degradation, and contamination.

Usually, the producer creating the externality does not incorporate the effects of externalities into their own calculations. Producers are interested in the maximization of their own benefits. They will only take into account their own private cost and their own private benefits, ignoring the social costs.

But from the point of view of ecological economics, externalities are not only considered in terms of money or costs. To understand environmental depletion, it is more useful to study the situation of biophysical indicators—the natural and rural metabolism and its trends.

It is not possible to find a solution to the global ecological degradation if there is no restriction in energy demands and economic expansion. One part of the world is trying to produce agrofuels, in particular the developing countries, and lands to produce these new energy crops (soybean, palm, corn) are obtained by crop displacement. Agrofuel production in countries such as Argentina, Brazil, Bolivia, Paraguay, Colombia, and several countries of Central America is having an enormous impact, not only in terms of agronomic transformations but also in terms of the following ecological issues:

- increasing deforestation
- landscape loss
- biodiversity loss
- nutrients depletion
- increase in environmental risks of contamination
- virtual water loss

Increasing Deforestation

One of the arguments in favor of industrial agriculture is the following: Till the beginning of the 1990s, it was asserted that implementing new technologies such as transgenic crops would increase productivity and put a stop to encroachment into pristine areas. This has not happened in any of the countries that started growing transgenic crops.

In the last 5 years, in countries such as Argentina or Brazil, transgenic crops (soybean and corn) are the main technology helping to expand the energetic agriculture model.

It has also not been considered how this sustained demand for new land in Argentina, Brazil, and Paraguay has caused cultivated areas to push directly into the forest mass, bringing along, because of the intense deforestation, extraction and burning of plant matter and a huge mass of greenhouse gases. In the Chaqueña region alone, the addition of 3,000,000 new hectares of crops (corn, soy, sunflower, rape, castor bean plant, and jatropha) is being considered.

Rates of deforestation in some regions of Argentina are similar to or higher than those in Africa (Figure 2). States such as Santiago del Estero, Santa Fe, or Misiones have very high rates of deforestation. A new law that was implemented in 2008 to try to put a stop to the deforestation is not functioning. In the meantime, another law to promote biofuel production in the country has been adopted.

Arable land is getting scarcer year by year. The available land is overexploited with production models that are unsustainable. The quality of the new added land decreases every day, and it is quickly exhausted through increasingly eroding processes.

In the Pampas, the main agricultural area for food production in Argentina, which covers around 55,000,000 hectares, there is no more rural land to

Figure 2
Deforestation Rates in Argentina

Pais/Region/Provincia	Tasa Anual de Deforestacion
Mundo	- 0,23 %
Africa	- 0,78 %
Sud America (1999/2000)	- 0,44 %
Sud America (2000/2005)	- 0,50 %
Argentina	- 0,85 %
Santiago del Estero	- 1,18 %
Santa Fe	- 0,95 %
Chaco	- 0,57 %
Misiones	- 1,33 %
Yungas	- 0,32 %

Source: Menendez (2007), Secretary of Environment and Sustainable Development, Argentina.

produce crops, including land that has been historically used in a rotation system for crop and cattle, and during the past 10 years this land has been displaced to permanent agricultural land (agriculturization). This is a very important process that not only changes the landscape of the Pampas but also puts at risk the nutrient balance.

The other very important process that Argentina is facing now is *pampeanization* (Pengue, 2005b). Pampeanization refers to the application of the rural, economic, financial, and agronomic model specific to the Pampas to those ecological regions of North Argentina and Central South America that are not similar to the Pampas. The process is being promoted for the current disposal of technology (transgenic crops adapted to the environmental conditions and no tillage) and the new demands for agrofuels. Landscape transformation of the environment in the north of the country is very significant (Pengue, 2008). Deforestation in the north of Argentina (Pengue, 2005a) implies loss of biodiversity, releasing of greenhouse gases, and loss of nutrients (Figure 3). Land that has been newly transformed in the north of the country during the past years amounts to 2,200,000 hectares.

Figure 3
Deforestation and Plantation of Transgenic Soybean in the North of Argentina (Las Lajitas, Salta)

Photo: Pengue (2004).

Increase in Environmental and Social Risks

The industrial agriculture (Pengue, 2005b) that is expanding throughout Latin America is eating into other production processes and is displacing hundreds of alternatives that are effective for local and regional consumption, which are also virtually threatened today.

Today, the discussion on the loss of food sovereignty and on the access to a balanced and sufficient diet is jeopardizing the rural economies of countries such as Argentina, which could easily double their diversified production instead of concentrating on soy monoculture, which currently accounts for around 50% of grain production, and has displaced other products such as milk, cattle, fruit, vegetables, and grains, and practically made them disappear.

Another issue relates to the price of food. If commodity prices keep rising (corn, soy, and many others), industries will compete to produce them (as is already the case with the food and energy agroindustries) ultimately leading to a lack of access to food for a large part of the population.

In addition, intensive agricultural production models have crushed family farming models (Pengue, 2008), which were the ones that yielded a larger variety of products aimed at rapid consumption by the local population. We must remember that over 50% of the food in Latin America is produced in the latter way.

In Latin America, two thirds of the population, that is, approximately 400 million human beings, do not have regular access to food. A president of the region recently promised three warm meals a day for the entire population. That president did not know that at that particular time there was literally not enough food in the country's territory, because he or she had oriented the country exclusively toward exports of commodities. Land is scarce and whatever fate we assign it will be closely linked to the fate of our own nations. In Brazil, this model can still expand, although obviously at an environmental cost, but in other countries of the region, this is no longer the case (e.g., Argentina).

The dilemma of choosing between biofuels or food is a reality in Argentina. There is a limit to the land available (Pengue, 2008), and no amount of increase in crop productivity can change this fact. There is a serious mismatch between one fate and the other, and this must be revised in an integrated rather than a partial manner.

H. T. Odum and E. Odum stated it clearly, saying that the world cannot continue to grow, consume energy, and depend on this model (Odum & Odum, 2001). Nicholas Georgescu Roegen,[5] the father of ecological economics, declared (in a manner that made us understand the importance of energy in the food system) that there is no such thing as a free meal.

Biodiversity Loss and Culture Loss

Latin America's natural and human resources could sustain its own long-term development. Some 23% of its land is suitable for farming, and another 23% is tropical rainforest (almost half the world's tropical rainforests are found in Latin America). Some 13% of the surface area is grassland, and the region holds 31% of the planet's available freshwater (Morello, 1983). Furthermore, it is home to rich reserves of renewable and nonrenewable energy and is the wealthiest region in the planet in terms of biodiversity.

Of the 12 so-called megadiversity countries, 5 are in Central and South America: Mexico, Colombia, Ecuador, Peru, and Brazil. Nevertheless, that wealth has not created the quality of life or environment for Latin America's peoples that it should have. This is because governments have focused on a defective development model that has excluded the majority of people, especially over the last 30 years.

Argentina is a meso diversity country with important endemic species (*Astronium balansae*, *Schinopsis balansae*, *Prosopis kuntzei*, *Tabebuia avellanedae*, *Caesalpinia paraguariensis*, *Patagonula americana*), which are in danger in the northeast and west of the country.

Over 1 million square kilometers in size, the Great Chaco forest is the second largest ecosystem on the American continent after the Amazon. It stretches across four countries: Argentina, Paraguay, Bolivia, and Brazil. It is one of the areas with the richest biodiversity on Earth.

The Chaco (Morello, 1983) is a vast flat outwash plain of dry forest, savanna, and grassland composed of sediments from the eastern slopes of the Andes. Approximately 630,000 km^2 (Naumann & Madariaga, 2003) or close to 60% of the region is in Argentina. The western portion of the Chaco is the driest and falls within the arid and semiarid zones. Vegetation of the Western Chaco consists of low forests with a dense understory of shrubs and prairie grasses. The eastern portion of the Chaco is considered dry, subhumid and is characterized by forests mixed with savanna (Morello & Hortt, 1987).

Forests are commonly known for the goods that they provide: timber, fuelwood, fodder, and other nontimber forest products. Less commonly known is the fact that forests also provide a number of crucial ecosystem services, very useful for society but whose value in economic terms is very low.

The role of the forest in sequestering carbon from the atmosphere, protecting upstream watersheds, conserving biodiversity and gene pools for future generations, providing landscape beauty, regulation of the water cycle and climate, soil formation, nutrient recycling, and plant pollination must be considered not only in economic terms but also in terms of the services provided for human beings.

In Argentina there is no more cleared land for cultivation. The new lands such as those from the agricultural borders in the Chaco region are rich areas. These areas should be valued for their total wealth. Their value includes economic value as well as ecological and social value related to biodiversity and conservation. These are potential agricultural lands (with limitations) but with more importance for biodiversity and conservation in terms of environmental services.

Around 4 million people live in the Chaco forest, most of them indigenous people who depend on the forest for food and water. Losing the forest's resources affects not only the local people's diet but their livelihoods as well.

Many varieties of precious hard wood trees grow in the Chaco forest, such as the iron wood tree (quebracho), which have been used to make sleepers for railways around the world for the past 100 years. When the forests are cleared to make way for soy plantations, these trees are often burnt or illegally sold. This leads to huge economic losses. The Chaco forest is home to the giant armadillo, which is facing extinction. When these forests are destroyed, any wildlife in the bulldozer's path is shot. Armadillos and other smaller mammals are frequently burned along with the groups of fallen trees stacked up along the newly deforested fields.

The iron wood tree is an endemic tree native to the Chaco. When cutters destroy this tree, they destroy an entire ecosystem that provided environmental services to the society.

The dry forests of the Chaco provide a variety of ecosystem services. Wood from red and white quebracho (*Schinopsis lorentzii* and *Aspidosperma quebracho blanco)* are used for charcoal production and tannin extraction. Several species of leguminous trees (*P. alba* and *P. nigra*) are important for their seed pods and wood, providing food for humans and livestock as well as material for lumber and medicinal products (Fernandez & Busso, 1997).

Several animals of the Chaco provide food for subsistence hunters as well as skins for commercial use, including tegu lizards (*Tupinambis rufescens* and *T. teguiztin*) and peccaries. Tegu lizards, which are found throughout South America east of the Andes, have traditionally been hunted for food, but today they are also being exploited for their skins. The skins are made into various leather accessories, especially cowboy boots, and used in international trade. In the 1980s an average of 1.9 million tegu skins from South America, including Argentina, were exported annually (primarily to the United States, Canada, Mexico, Hong Kong, Japan, and Korea; Fitzgerald, 1994) in an illegal way.

Three species of peccaries are hunted by humans for their meat and hides. Two species, the collard peccary (*Tayassu tajacu*) and the white-lipped peccary (*T. pecari*), are more widespread than the Chacoan peccary (*Catagonus wagneri*). The much smaller geographical range and population of the Chacoan peccary as well as its diurnal habits and limited defense strategy (standing its ground rather than fleeing) have made it much more susceptible to hunting than the other peccaries.

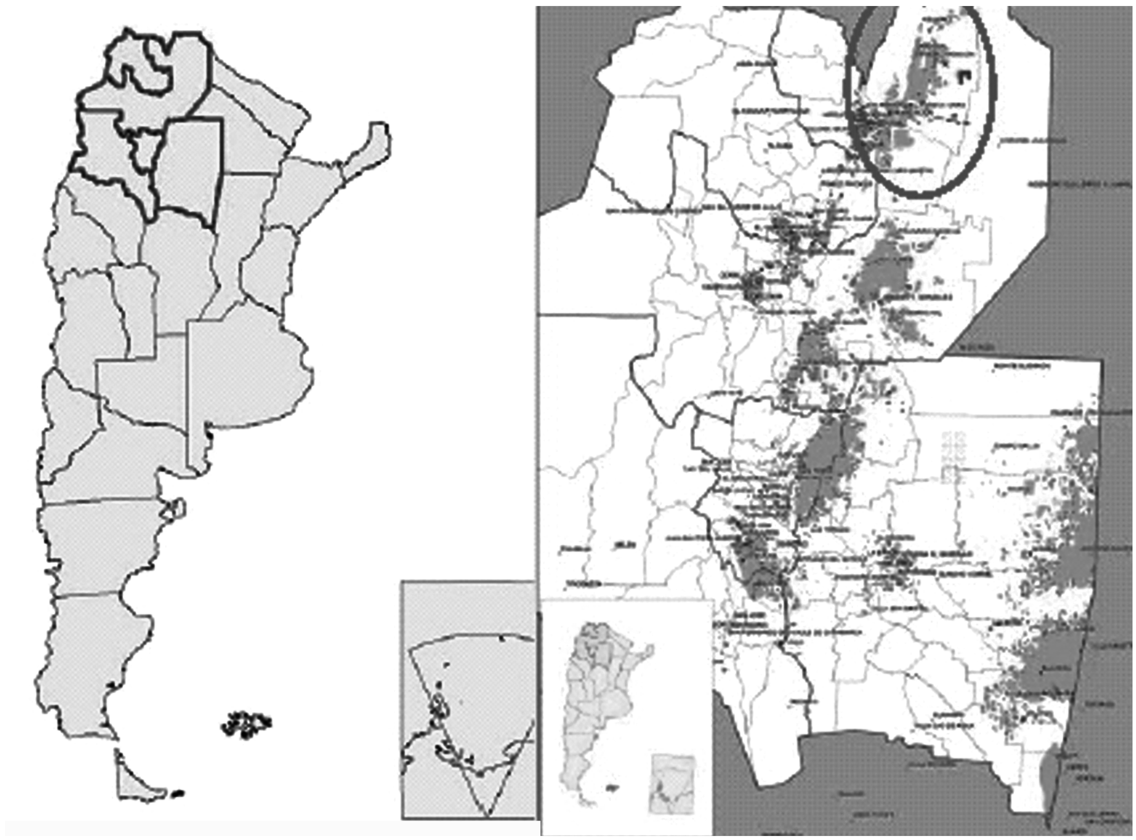
The honeycomb of native honeybees is a very important resource for native people, who have used it for centuries for food and natural medicines. Native honey bees, similar to other species, are being affected by pesticides and burning.

The entire Chaco region (including parts of Bolivia and Paraguay as well as Argentina) supports roughly 2,000 species of plants, of which at least 90 are endemics (Noss, Mares, & Diaz, 2003). At least 85 species of small mammals are supported by the Chaco, most notably the chancho peccari (*Catagonus wagneri*). The semiarid thorn forest and steppe of the region is considered to be a favorable habitat for this animal, with legume seeds, roots, and cacti being important components of its diet (Nowak, 1995).

Rodents exhibit a high degree of endemism within the Chaco, including the recently discovered Chalchalero vizcacha rat (*Salinoctomys loschalchalerosorum*), described as possibly one of the rarest mammals in the world, with only two specimens recorded from Salinas Grandes, Argentina (Mares et al. as cited in Noss et al., 2003). Bird species number nearly 500, with several endemics. Flagship bird species of the Chaco and neighboring regions include the greater rhea (*Rhea americana*), king vulture (*Sarcoramphus papa*), black-chested buzzard eagle (*Geranoaetus melanoleucus*), and crowned eagle (*Harpyhaliaetus coronatus*). Many of these individuals such as rats, snakes, and birds are the first victims of deforestation.

People are not in a better situation as far as diversity is concerned. The total human population for the

Figure 4
Main States of Argentina Where Sorghum Resistant to Glyphosate Is Being Spread



Source: Olea (2008)

entire Chaco region is estimated at 2,810,000 (Noss et al., 2003). For Argentina alone, the population is approximately 2,600,000, or nearly 93% of the region's population. The largest cities in the Argentine Chaco are Resistencia, Formosa, and Santiago del Estero. With more than 75% of the Chaco population living in urban areas, human population density for the region in general is very low; for the Argentine Chaco, the density is about 4 people per square kilometer (Noss et al., 2003). People who live in dispersal areas and little towns are generally criollos[6] (peasants) or indigenous people.

Despite the Chaco's richness in cultural diversity and low population densities, its residents do not enjoy a high standard of living. Argentine Chaco Indians have generally become more sedentary as a result of colonization and rely on wage labor in sugar factories and the timber industry, and work as ranch hands. Decline in the ecosystem services of the Chaco has curtailed the possibility of the indigenous peoples maintaining a traditional sustenance existence (Miller, 1999).

The current demand for soybean, its prices in the global market, and devaluation of these dry lands in its production has brought enormous pressure on all these people. Big farmers from other states (Cordoba, Buenos Aires, Santa Fe) are entering the Chaco and buying the lands of indigenous people, destroying their homes, and putting their lives under risk (Branford, 2004).

The change in ecosystem services brought about by intense grazing and soybean crop production, include alteration in the composition of the flora, increased soil erosion, floods in the cities of the basin (Tartagal, Santa Fe), increased invasion of exotic plants, and facilitation of the transmission of infectious diseases (Bertonatti & Corcuera, 2000).

Bioinvasions are a new consequence directly related to the monoculture system of continuously sowing soybean. Evolution of glyphosate-resistant Johnsongrass (*Sorghum halepense*) in glyphosate-resistant soybean is one of these results (Vila-Aiub, Balbi, Gundel, Ghersa, & Powles, 2007).

Figure 5
Land Invaded by *Sorghum halepense* in the Surroundings of Villa Angela (Chaco State, Argentina)

Source: Pengue (2007).

The appearance of resistance in several weeds, which is related to industrial agriculture, is a very importance case (Tuesca, 2007), relevant in economic and ecological terms. The resistance to glyphosate in Sorgo de Alepo or Johnsongrass[7] (Service, 2007) is a result of the intensification in transgenic soybean expansion in the north of the country. To date, nearly 200,000 hectares in several parts of the north of the country have been invaded by this new biotype of resistant sorghum (Figure 4).

The glyphosate-resistant strain developed through the process of natural selection following years of glyphosate spraying in the soybean fields. In the northeast and west of the country, farmers were asked to increase the application of glyphosate, including in combination with others herbicides such as 2,4 D. In this area, weed control was always more complicated.

Another consequence of industrial agriculture expansion is the increasing costs of herbicides, which means that small- and medium-scale farmers cannot use herbicides to control weeds.

In some cases, the situation puts so much pressure on these peasants that they leave their lands (because they have neither the money to apply herbicides nor the machinery for mechanical control).

Sorghum halepense is a conspicuous weed that invades the land rapidly, with serious economic and social consequences for the small-scale farmer: migration or displacement to other land (Figure 5).

Estimates by weed scientists in Argentina show that if 25% of the rural surface were invaded by SARG (*Sorghum halepense* resistant to glyphosate), the cost to control only this new weed will increase to US $50.27 millions, and if the complete surface were involved, the cost would rise to US $201 millions (Tuesca, Nisensohn, & Papa 2007). In conclusion, only one weed is enough for the duplication in the herbicide cost related to soybean.

Nutrient Depletion

One of the most important effects of intensification of agriculture is related to the depletion of nutrients in the soil. The situation has been discussed in-depth in Pengue (2005b). Soil fertility depletion in farms is one of the fundamental biophysical causes for declining per capita food production, which could affect the stability and food security in several countries of South America.

The practice of removing part or all of the crops grown in the soil accelerates the loss of nutrients from the soil. The cycling of nutrients from plant uptake and release is interrupted by crop removal. Unfortunately, the risk of nutrient stress in South America is very important and more important than relevant problems related to drainage, flooding, frost, and other environmental limitations (Table 2).

Figures are increasing now, with the increasing demand for soybean production and exportation in Brazil and Argentina. In the case of Argentina, extraction of the more important nutrients is relevant, especially what has been happening during the last 10 years (Figure 6; Pengue, 2006).

Soybean cultivation has always led to erosion, especially in areas where it is not part of a long rotation. Soil loss has reached an average rate of 16 tons per hectare per year in the U.S. Midwest, far greater than is sustainable, and soil loss levels in Brazil and Argentina are estimated at between 19 and 30 tons per hectare per year depending on management, slope, and climate. Farmers wrongly believe that no-till systems mean no erosion. No-till agriculture can reduce soil loss, but with the advent of herbicide tolerant soybean, many farmers now cultivate in highly erodible lands. Research shows that despite improved soil cover, erosion and negative changes in soil structure can still be substantial in highly erodible lands if weed cover is reduced.

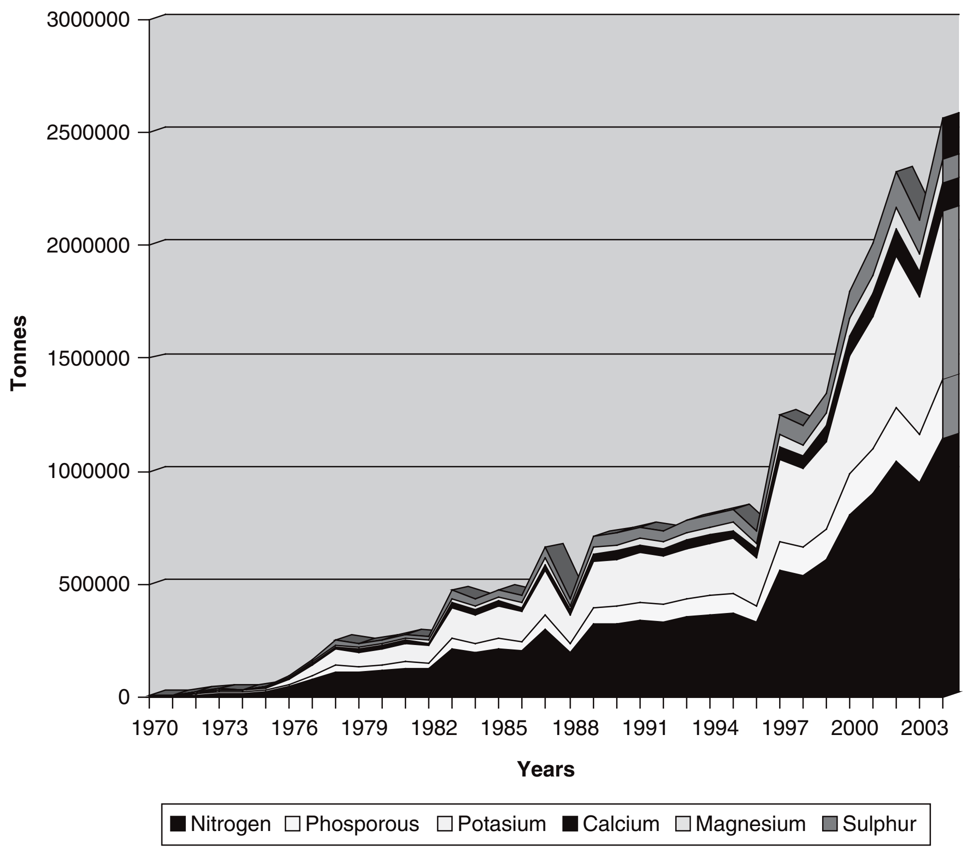
Large-scale soybean monoculture is rendering the Chaco soils unusable. In areas of poor soils, fertilizers

Table 2
Resources in Global Lands and Their Limitations for Agriculture (percentage)

	Drought	Mineral Stress	Peatbog	Flooding	Frost	No Limitation
North America	20	22	10	10	16	22
Central America	32	16	17	10	—	25
South America	17	47	11	10	—	15
Europe	8	33	12	8	3	36
South Asia	43	5	23	11	—	18
North Asia	17	9	38	13	13	10
Southeast Asia	2	59	6	19	—	14
Australia	55	6	8	16	—	15
Total soils	28	23	22	10	6	11

Source: FAO (1995).

Figure 6
Nutrient Extraction From Soil During the Seasons 1970/1971 through 2004/2005 for Soybean in Argentina



Source: Pengue (2006).

and lime have to be applied heavily within 2 years. In Bolivia, soybean production is expanding toward the east, and in many areas, soils are already compacted and suffering severe soil degradation. One hundred thousand hectares of soybean-exhausted soils were abandoned for cattle grazing, which in turn further degrades the land (Altieri & Pengue, 2006). As land is abandoned, farmers move to other areas where they again plant soybeans and repeat the vicious cycle of soil degradation.

In Argentina, intensive soybean cultivation has led to massive soil nutrient depletion (Figure 6; Pengue

2006). Continuous soybean production has extracted an estimated 1 million tons of nitrogen and about 300,000 tons of phosphorous per year. The estimated cost of replenishing this nutrient loss via fertilizers is US $2,000 million. Argentina is losing by year, through not accounted externalities, around 20% of the earnings from soybean exportation. The increased levels of nitrogen and phosphorus found in several river basins of Latin America is certainly linked to the increase in soybean production. This other externality, that is, the contamination of the river basins, is not being considered yet. Depletion of nutrients and agrochemical contamination are being confirmed in the main basins of Argentina (Del Plata Basin, Lujan River Basin, and others), and the contaminants end up directly in the city of Buenos Aires via the Parana river.

Virtual Water in Biodiesel Exportation

Virtual water is the amount of water that is embedded in food or other products that is needed for its production. With the trade of food crops or any commodity (biodiesel, bioethanol), there is a virtual flow of water from producing and exporting countries to countries that import and consume those commodities. A water-scarce country can import products that require a lot of water for their production rather than producing them domestically. By doing so, it allows real water savings, relieving the pressure on their water resources or making water available for other purposes. Countries "rich" in these resources could be affected by overexploitation.

The water footprint is an indicator of water use that looks at both direct and indirect water use of a consumer or producer. The water footprint of an individual, community, or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

The water footprints of biofuels are based on the virtual water content of the crops calculated by Chapagain and Hoekstra (2004). In their study, they have calculated only one virtual water content for a crop for each country. If the country in question is large, like for example Argentina or Brazil, the growing conditions can be different in different parts of the country. So as there is only one virtual water content for a crop in these large countries as well, the virtual water contents of the crops are not the exact values either.

The production of biomass for food and fiber in agriculture requires about 86% of the worldwide freshwater use. In many parts of the world, the use of water for agriculture competes with other uses such as urban supply and use for industrial activities. In a scenario of increasing degradation and decline of water resources, a shift from fossil energy toward energy from biomass puts additional pressure on freshwater resources.

There are large differences in the water footprints for specific types of primary energy carriers. As a whole, the water footprint of energy from biomass is 70 to 400 times larger than the water footprint of other primary energy carriers (excluding hydropower; Gerbens-Leenes, Hoekstra, & Van der Meer, 2008). Nevertheless, it depends on crop type, agricultural production system, and climate. The trend toward more energy use in combination with increasing contribution of energy from biomass will bring with it a need for more water. This causes competition with other claims, such as water for food crops.

When crops are used for bioenergy, it is more efficient to use the total biomass, including stems and leaves, to generate electricity than to use only a fraction of the crop (its sugar, starch, or oil content) to produce biofuel. The weighted average water footprint of energy (m^3/GJ) is a factor of two to four smaller for bioelectricity than for bioethanol or biodiesel. This is because for electricity, the total biomass can be used, whereas for ethanol or biodiesel only the sugar, starch, or oil fraction of the yield can be used. In general, when considering biofuels for transportation, the water footprint of bioethanol is smaller than the water footprint of biodiesel (Gerbens-Leenes et al., 2008).

However, the consumption time is also relevant. According to de Fraiture, Giordano, and Yongsong (2007), on average, 2,400 liters of water are withdrawn to grow the necessary amount of maize for 1 liter of ethanol in China. In India, on average, 3,500 liters of irrigation water is withdrawn to grow the necessary amount of sugarcane for the production of 1 liter of bioethanol (Melkko, 2008). According to Varghese (2007), the production of 1 liter of ethanol requires anywhere from 1,081 to 1,121 liters water when produced from maize grown in the United States. When corn is irrigated, the water need is higher—about 1,568 liters (Melkko, 2008). When bioethanol is produced from sugarcane grown in Brazil, between 927 and 1,391 liters of water are needed to produce 1 liter of ethanol (Melkko, 2008).

Virtual water is related to the water necessary to produce 1 ton of a specific crop. In the case of Argentina, virtual water balance for the case of soybean, which is exported completely, is negative but shows the interaction between the exchange of grains

Table 3
Net Balance of Virtual Water for the Soybean Argentina Production (millions of cubic metric tons)

Soybean/Year	2000	2001	2002	2003	2004
Virtual water imported	0.0075	0.0080	0.0097	0.0095	0.0094
Virtual water exported	29.86	33.33	38.68	35.08	42.55
Net virtual water balance	–29.85	–33.32	–38.67	–35.07	–42.54

Source: Pengue (2006).

in the region between countries (Bolivia, Paraguay, and Brazil export an amount of grain via the Paraguay Parana Basin; Table 3).

Virtual water is a physical indicator that can help estimate the externalities of the implementation of an agroenergetic model, considering biomass from crops as a core. The water footprint (Gerbens-Leenes et al., 2008) shows that the demand for freshwater from biomass to produce energy is higher than that for other sources of energy (wind, solar, natural gas, oil). As a whole, the water footprint of energy from biomass is 70 to 400 times larger than the water footprint of the other primary energy carriers (excluding hydropower). Water in countries such as Argentina, Brazil, Paraguay, or Bolivia is not being considered a limitation for crop production. Numbers now demonstrate the importance of beginning to estimate this resource as part of the correct function of rural metabolism.

Final Comments

Soybean cultivation expansion in Latin America represents a recent and powerful threat to biodiversity in Brazil, Argentina, Paraguay, and Bolivia. Agrofuels are an important part of this model, which must be considered from a holistic point of view. First, production of biofuels is pushing up prices of food because of the competition between the energy industry and the food industry.

In ecological terms, externalities of the intensification of the agricultural energy model are not being considered. Loss of biodiversity in the north of Argentina, deforestation, and degradation of environmental services are the main issues. Ecological economics puts the focus on studies about the transformation of biophysical indicators. Nutrient depletion is a very well-known indicator of soil degradation and degradation of the environmental stability of the system. Virtual water and water footprints are indicators that demonstrate the trends of increasing demand on freshwater. Freshwater is one of the most valuable resources in the north of the country because of its scarcity (The Great Chaco).

The effects on global warming from agrofuels is clear, but they also have other disadvantages. GM soybeans are much more environmentally damaging than other crops, partly because of their unsustainable production requirements and partly because their export focus requires massive transportation infrastructure projects, which open up vast tracts of land to other environmentally unsound economic and extractive activities. These are serious issues because agrofuel demand is increasing.

The production of herbicide-resistant soybean leads to other environmental and agronomic problems, such as the appearance of herbicide-tolerant weeds and resistance in one of the most conspicuous weeds in South America. The appearance of resistance in Johnsongrass (*Sorghum halepense*) is an economic and ecological issue, which should be viewed as a bioinvasion by a new, dangerous specie that cannot be controlled with the old package of RR soybean + glyphosate.

Notes

1. We called agrofuels all biomass that come directly from a primary crop that could be useful either for food (soybean, corn) or energy production. But there can be much competition for this source, which would be a threat to food security. Biofuels are seen here as second generation biomass, which could be used to produce energy with no competition between the two industries. Biofuel is defined as solid, liquid, or gaseous fuel derived from relatively recently dead biological material and is distinguished from fossil fuels, which are derived from long-dead biological material. Theoretically, biofuels can be produced from any (biological) carbon source.

2. BIOFAA is a project managed by Federación Agraria Argentina (Argentine Agrarian Federation), an organization that focuses on small- and medium-scale farmers (www.iade.org.ar/modules/noticias/article.php?storyid=2235).

3. Virtual water is the amount of water that is embedded in food or other products that is needed for its production.

4. Human Appropriation of Net Primary Productivity (HANPP).

5. *The Entropy Law and the Economic Process* (1971). Georgescu-Roegen's claims, among others, were that an economy faces limits to growth, for which he invoked the Second Law of Thermodynamics.

6. In Argentina, locals of Argentina's interior northern and northwestern provinces are called criollos.

7. *Sorghum halepense* is an extremely invasive noxious weed with a worldwide distribution. High seed production and an extensive

rhizomal system make it difficult to eradicate. This species has a number of detrimental effects, including toxicity to grazing stock, fire risk during summer, and competitive exclusion of other plants. It reduces soil fertility, acts as a host for crop pathogens, and is a known allergen.

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