Biocombustibles en Argentina
Impactos de la producción de soja sobre los humedales y el agua

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Lorena P. Herrera, José Luis Panigatti, María P. Barral y Daniel E. Blanco

WETLANDS INTERNATIONAL

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Fundación para la Conservación y el Uso Sustentable de los Humedales
Wetlands International Argentina

2013

WETLANDS INTERNATIONAL

Biocombustibles en Argentina: impactos de la producción de soja sobre los humedales y el agua / Lorena P. Herrera ... [et.al.]. - 1a ed. - Buenos Aires: Fundación para la Conservación y el Uso Sustentable de los Humedales, 2013.
104 p. : il. ; 30x21 cm.

ISBN 978-987-24710-8-8

1. Ecología. 2. Soja. 3. Humedales. I. Herrera, Lorena P.
CDD 551.41

ISBN: 978-987-24710-8-8

Esta publicación puede citarse como sigue */ This publication should be cited as follows:*

Herrera, L.P., J.L. Panigatti, M.P. Barral y D.E. Blanco. 2013. Biocombustibles en Argentina. Impactos de la producción de soja sobre los humedales y el agua. Fundación Humedales / Wetlands International. Buenos Aires, Argentina.

Publicado por / *Published by*: Fundación para la Conservación y el Uso Sustentable de los Humedales / Wetlands International.

http://lac.wetlands.org/

Foto de tapa: Agricultura en los alrededores del Delta del Paraná, por Rubén D. Quintana.
Cover photograph: Agriculture surrounding the Parana Delta, by Rubén D. Quintana.

Diagramación y coordinación gráfica / *Designed by:* Pablo Casamajor

Impreso en / *Printed by:* Talleres Gráficos Leograf S.R.L., J. I. Rucci 408, Valentín Alsina - Pcia. de Bs. As., Argentina.

Impreso sobre / *Printed on:* papel obra de 90 gramos y tapas en cartulina ilustración de 300 gramos.

La presente publicación ha sido realizada gracias al apoyo de IUCN-NL, Wetlands International y Both ENDS en el marco de la Alianza Ecosistemas.

The present publication was carried out thanks to the support of IUCN-NL, Wetlands International and Both ENDS in the framework of the Ecosystem Alliance.

Prologue

The world is beginning to realize the pressures to which the planet is subject to towards satisfying (or not satisfying) the demands of its people. These pressures produced, are producing and will produce changes to ecosystems and their fundamental properties, while directly and indirectly influencing the provision of ecosystem goods and services which support societies' well-being. Some of these changes include climate change, changes in atmospheric composition, major shifts in land use, soil degradation, and biodiversity loss and habitats due to demands of a growing population, which requires more and better food, fiber and energy, among other needs.

This publication addresses the problem of the great boom in soybean production in Argentina in the context of biofuels production, and how this process affects and could further affect wetlands, the quality and quantity of water, and consequently, the human population. It should be noted that this study presents an analysis from the perspective of conservation of wetlands and biodiversity, and obviously, its concepts and thoughts reflect the concern as perceived from this perspective.

This body of work provides a very comprehensive compilation of information on the legal framework, the birth and development of soybean production, and the impetus given to the production of biofuels, as an effort to provide a solution to the emerging energy crisis in Argentina and worldwide. The authors provide evidence for concerns about the effects on the environment from the externalities that are generated, and will be generated. Among the most notable effects mentioned are the negative impact on the integrity and quality of soil, water, biodiversity and its services, and the general state of wetlands connected to agricultural areas. Also, social changes related to land tenure and migration processes arising from technological changes associated with soybean production. An interesting feature of this book is that the authors do not confine themselves to the diagnosis, but produce a set of recommendations that, if implemented, could likely improve the environmental amicability of soybean production significantly, not only for biofuels but also for other production purposes.

The analysis made in this publication also displays a balance between costs, both environmental and social, and benefits to production associated with soybean expansion in ecosystems, including wetlands, which can be interpreted as cancelling one another, so that the expected results to solve the energy crisis are not obtained. In addition, the developmental processes based on a monoculture could leave ecosystems at risk and lead to loss of socio-environmental resilience. This fundamental property of sustainability is the capacity social-ecological systems retain to continue to produce goods and services, while maintaining the structure and function of ecosystems, in the face of changes and disruptions from uncertainties linked to climate variables and human activities.

Undoubtedly, arguments in this publication will meet resistance from the production sector, but it defines a space for reflection towards a comprehensive analysis and dialogue across the spectrum from conservation to production. From this will emerge virtuous and constructive proposals for the joint management of the environment and the necessary compatibility between production and conservation.

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Foreword and Acknowledgments

Currently soybean accounts for over 60% of the cultivated area of the country and is the main crop for biodiesel production, making Argentina the world's fourth largest producer of biofuels and the largest exporter. This publication is the result of a deep analysis of national and international information, with the goal of compiling and analyzing current information regarding expansion of soybean crop in Argentina as well as current and potential impacts on wetland ecosystems.

The first part is about biofuels in general and soybean crop cultivation in Argentinian territory. Drivers for biofuel development and the technical aspects related to soybean crop production are described as well. A characterization of the areas used for soybean crop in Argentina is included, represented in two major production regions: primary zone (production core zone) and a secondary zone (expansion zone), set in the context of current environmental legal framework. Lastly, wetland ecosystems of Argentina are presented and their location in relation with the two soybean crop production zones is described.

Finally, based on the information collected, we analyzed an discussed the impacts of soybean production over wetlands ecological integrity and their associated good and services in Argentina, with focus on wetlands distribution and abundance, soil health, water quality and availability, biodiversity and social development.

We want to thank the Ecosystem Alliance initiative (UICN-NL, Wetlands International and Both ENDS) for making possible this publication.

- To the experts interviewed: Cristina Arregui, Jaime Bernardos, Julie Brodeur, Eugenio Cap, Pablo Collins, José Luis Costa, Ana M. Gagneten, Jorge Hernández, Mercedes Marchese, Jorge Medina, Roberto Olivares, Laura Orduna, Claudia Oroná, María C. Panigatti, Carlos Paoli, Juan C. Parera, Pablo Peraud, Jorge Peyrano, Miguel Pilatti, Rubén Quintana, Diego Rodríguez, Marcelo Romano, Martín R. Romano, Pedro Schaefer, Enrique Sierra, María Elena Zaccagnini and Juan C. Zembo.

- To Jorge Hilbert for his comments on a critical reading of the first document of this publication.

- To Carmen Penedo for the revision and editing work.

- To Jeffrey Thompson for his colaboration in the English translation of the Prologue and Executive Summary.

- To Claudio Baigún, Jorgelina Oddi, José Luis Panigatti, Donald Peck, Rubén D. Quintana, Marcelo Romano, Jimena Frojan / Round Table of Responsible Soy (RTRS) and Fernando Salvucci, for the photographs that illustrate this publication.

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Executive Summary

Biofuels are a response to the rapid depletion of fossil fuels and as a fuel which reduces the emission of greenhouse gases compared to fossil fuels. However, the increased use of biofuels from agricultural crops has led to a debate about the impacts of these products on the environment. Mainly they pose a risk to biodiversity because the high profitability of biofuels has led to replacement of natural or semi-natural areas, further marginalizing indigenous and local communities. This process could also be producing more emissions of greenhouse gases than it avoids. With the introduction of glyphosate-resistant soybeans in Argentina in 1996 and the use of no-till technologies the implantation of soybean grew at an unprecedented rate. Currently soybean accounts for over 60% of the cultivated area of the country and is the main crop for biodiesel production; making Argentina the world's fourth largest producer of biofuels and the largest exporter.

The main factors affecting the production of soybean that affect the distribution and abundance of wetlands translate directly into their disappearance and indirectly to their degradation and the loss of connectivity and associated biodiversity. This leads to the loss of valuable ecosystem functions and, consequently, to the loss of goods and services that wetlands provide to society. These services include, but are not limited to, the decreased intensity of the effects of flooding on neighboring ecosystems, the presence of potable water, and the production, retention and fixation of sediment and pollutants, which in turn improves water quality, the storage of organic soil carbon, forage production, the maintenance of key habitats within the landscape, etc.

In relation to soil health, the increasingly intensified agricultural management, dominated by soybean production, leads to the loss of soil cover through reduced crop stubble, accelerated uptake of nutrients, loss of soil biodiversity, changes hydrological cycles (especially in those areas with low agricultural suitability), salinization, alkalization, acidification and soil compaction, among others.

While soybean production can affect the quality and availability of water through pollution and eutrophication of water bodies in agricultural areas, the evidence suggests that these impacts would be relatively low because the chemicals used in soybean production have low persistence in water and/or are neutralized by sediments or suspended particles. Still, there is evidence of negative impacts on the flora and fauna of wetlands adjacent to soybean crops, such as low population size of aquatic organisms, physiological/ethological changes in amphibians and fish, algal toxicity to agrochemicals, and changes in riparian community structure.

Finally, in relation to social aspects, high mechanization and reduced demand for labor for soybean production has led to the concentration of land tenure and the loss of small producers, along with the loss of jobs, traditional livelihoods and rural culture.

The evidence gathered in this paper shows that despite the availability of technology for higher crop yields and quality with lower environmental impacts, the lack of planning and economic interests lead to crop management with little to no attention to conservation of natural resources, especially wetlands. Cultural practices and expansion of soybean production into environmentally sensitive and fragile areas are the most important and of greatest concern in regard to the predominant production model. However, in most cases the importance of wetland is not yet known, even from the point of view of production, resulting in serious degradation and environmental impacts.

This report presents a series of recommendations for soybean production to be compatible with both the maintenance of functions provided by ecosystems, such as local community development. In this regard, it is essential to promote environmental planning as a key tool to restrict the expansion of soybean cultivation from entering areas of high value for biodiversity conservation and to promote measures to ban cultivation along the periphery of rivers, streams, lakes and ponds to prevent pollution by agrochemicals while creating biodiversity refuges. The development of guidelines for "good agricultural practices", maximizing the incorporation of the environmental component and the involvement of producers is key to promoting environmental monitoring, integrated pest management and responsible use of chemicals on farms dedicated to soybeans. Thus, it is necessary to identify specific indicators to monitor socio-environmental impacts of soybean expansion on wetlands.

Supporting and encouraging research related to water pollution would allow the establishment of management guidelines for mitigating the effects of soybean production, generate alternative technologies in the medium term to reduce the use of glyphosate, and to build and strengthen interactions among professionals in scientific and technological disciplines related to environmental research, sustainable production programs, extensionists and policy makers. Finally, it is essential to raise awareness among farmers and other actors in the soybean production chain on the importance of wetlands and their role as suppliers of key goods and services to society, and in particular agricultural production.

CHAPTER 1

Introduction

Recent global economic growth has lead to accelerating depletion of fossil fuel resources resulting in the need to develop cost effective alternative energy sources while generating a minimal impact on the environment. Biofuels are promoted towards this end, primarily as a product which emits less greenhouse gases (GHG) compared to fossil fuels; however, the increased use of biofuels has led to debate on their impacts. It is argued that biofuels represent a risk to biodiversity, mainly due to habitat conversion for cultivation, marginalizing indigenous and local communities, and producing more emissions of GHG than it prevents (FAO 2008).

Given the growing worldwide demand for biofuels, which is expected to increase in the future (Doornbosch y Steenblik 2007, FAO 2008), it is also expected that the land area dedicated to biofuel production will increase as well (FAO 2008). Because technology and biofuel policies are evolving at a rapid pace, it is difficult to generalize the specific impacts of biofuels since the effects of each fuel type and production system vary (Righelato and Spracklen 2007, Fargione *et al.* 2008, Searchinger *et al.* 2008). There are few data on the effects specifically associated with increased production of biofuels, although most are similar to those already known for agricultural production: decreased availability and water pollution, soil degradation, nutrient depletion, biodiversity loss and reduced agricultural diversity, in addition to competing for soil destined for food (FAO 2008). Therefore, to fully understand the possible effects on the environment, natural resources and biodiversity stemming from biofuel production, we must consider the direct and indirect land use changes caused by increased production of biofuels.

Argentina is undertaking this critical review of biofuel production, has signed the Kyoto Protocol in July 2001 (National Law 25.438), participating in the Article 12 which promotes clean development, and is interested in both ensuring the provision of fuel for economic growth and contributing to the conservation of natural resources and environmental improvement, as established by various laws and decrees. Additionally, Argentina has comparative advantages for developing alternative

Fields with soy in Ramallo, Buenos Aires.

Rubén D. Quintana

energy sources, particularly from agricultural products such as biodiesel and bioethanol, since Argentinian oilseed production is highly efficient and its sector of biofuel market is significant (Scheinkerman de Obschatko y Begenisic 2006).

During the 70's the use of no-till agriculture expanded, considering that environmental management is key in order to make agriculture and food production in a sustainable way, minimizing negative impacts and improving all aspects that scientific knowledge provide. With time, this new paradigm began to take shape and in 1989 the Argentinean Association of No-till Producers (Aapresid in Spanish) was formed adhering to a set of Good Agricultural Practices including crop rotation, site-specific crop varieties and intensity in management, appropriate use of agrochemicals, plant nutrition and replenishment of nutrients to the soil, incorporation of digital technology and precision agriculture and incorporation of cover crops to maximize soil biology (Peiretti 2011).

With the introduction of glyphosate-resistant soybeans (*Glycine max*) in Argentina in 1996 and its strong applicability to its use with no-till technology, soybean production began to increase at an unprecedented rate. Today soybean accounts for over 60% of the cultivated area in Argentina and is the main crop used for biodiesel production, making Argentina the fourth largest producer of biodiesel and the largest exporter worldwide (Bragachini *et al.* 2011).

Due to its high profitability and thanks to the technologies that have been developed in relation to this crop, soybean has spread to areas where agriculture would have never been possible. In several areas, this expansion is at the expense of the destruction of native ecosystems, such as forests and wetlands. Many are the cases where wetlands have been drained totally to allow the introduction of soybeans and many more those where these ecosystems have been degraded because of agrochemicals contamination.

The objectives of this publication are to provide updated information on the production of biofuel from soybeans in Argentina and discuss current and potential impacts of this production on wetland ecosystems, their ecological integrity and the associated goods and services.

Chascomús Lagoon, Buenos Aires.

Claudio Baigún

CHAPTER 2

Biofuels in Argentina

National and international legal and policy framework

Environmental legislation

With the Stockholm Conference (1972) and the United Nations Conference on Environment and Development (1992) environmental issues in Argentina began to emerge. Article 41 of the national constitution establishes the right of all people to enjoy a healthy environment and the responsibility to preserve it. At the same time it establishes the responsibility of the nation to determine minimal standards of environmental protection and the responsibility of the provinces to meet and enforce those standards. In 1993, Argentina joined the United Nations Convention Framework on Climate Change through Law Nº 24.295. Later, in 2001, adopting the Kyoto Protocol with Law Nº 25.438.

Under these minimal standards the first law to be enacted in Argentina was Nº 25.675: The General Environmental Law. Since the creation of this law there were other specific regulations of environmental protection, such as:

- National Law Nº 26.331: Minimum Standards of Environmental Protection of Native Forests, which set out basic guidelines for the enrichment, restoration, conservation, sustainable use and management of native forests.
- National Law Nº 25,688: Environmental Water Management, which provides minimal standards for water preservation and wise use. In Article 8, this act refers to the protection of wetlands, stating that "… *the national authority may, upon request of the competent judicial authority, declare critical areas with special protection within certain watersheds due to their natural characteristics or environmental interest"*.

Regarding wetland ecosystems, Argentina is a contracting party to the Convention on Wetlands or Ramsar Convention (Ramsar, Iran, 1971), which was ratified by National Law Nº 23.919 in 1991 and issued by Decree 693. Amendments to the Convention were approved by National Law Nº 25.335 in 2000. Upon joining the Ramsar Convention, each Contracting Party is obliged by Article 2.4 to designate at least one wetland site for inclusion in the List of Wetlands of International Importance. At present, Argentina has 20 Ramsar Sites which protect an area of 5,339,586 ha. In addition to the Ramsar Sites, countries that adhere to the Ramsar Convention should develop and implement their planning so to promote, as far as possible, the wise use of wetlands in their territory.

Consultations with decision makers from universities, public and private agencies, professional consultants and farmers, stress that the existence of national laws and provincial legislation protecting the environment is sufficient but there are shortcomings regarding implementation, such as lack of updating, insufficient coordination among agencies that implement laws, contradictions of certain rules, etc. The most significant and serious barrier towards sustainable development is the failure to apply, respect, and control or monitor the compliance of regulations. The laws and regulations lack implementation both in space (geographical inequity) and in time (discontinuity).

Public are not encouraged to abide by the law for economic reasons, status, education or societal pressure. This is very negative for the conservation of natural resources, since conservation depends, in part, on an appropriate regulatory framework to monitor the decisions made in the private sector.

Biofuels and soybean

In the case of biofuels, in 2006 the National Law Nº 26.093 Plan promoting the Production and Sustainable Use of Biofuels was enacted. This law aims for promoting biofuel production for the domestic market through subsidies exclusively for agricultural societies, directed towards regional economies and strongly promotes the consumption of biofuels by the agricultural sector. The law establishes that for 2010 the blending of biofuels with fossil fuels comprising 5% biodiesel in diesel fuel and 5% bioethanol in gasoline. This also is expressed in Article 13 of Regulatory Decree (109/07), identifying them as B5 (fuels with 5% biodiesel) and E5 (fuels with 5% bioethanol). This percentage may increase (depending on market variables) or decrease (in situations of scarcity). Article 10 of the Regulatory Decree grants the possibility to the Enforcement Authority (Ministerio de Energía - Ministerio de Planificación Federal, Inversión Pública y Servicios) to advance the mandatory use of biofuels below 5% if it considers that conditions are reasonable. In the case of increasing the percentage of biofuels in mixes there will be an announcement of at least 24 months in advance.

In July 2010 Resolution 554/2010 was established, which mentions an increase in the proportion of biodiesel mixed with fossil fuels to 7%. The basis for this increase lies, mostly, in that biodiesel processing companies have the production capacity and product range in the

Donald Peck

Organic Soybean in Estancia Las Dos Hermanas, Córdoba.

quantities necessary to effecting increase the current percentage of biodiesel in diesel fuel in the domestic market. In this way, this meets the demands of diversifying the energy matrix, promising growth of the national agricultural sector and the overall economic activity[1].

In 2006 the Roundtable for Responsible Soy (RTRS) was formed, an international initiative that promotes the use and responsible growth of soy production through the commitment of key actors in the production chain via setting a global standard for responsible production[2]. This initiative aims to facilitate a global dialogue on economically viable soy production that is socially equitable and environmentally appropriate. In 2011 the RTRS adopted the standard for responsible soy production, which includes requirements to conserve areas of high conservation value, promoting best management practices, ensure fair working conditions and respect the claims of land tenure. Currently, it is working on the development of national interpretations of the standard in key countries such as Argentina, Brazil, Paraguay, India and Bolivia.

Agriculture investments and drivers for biofuel development

The expansion of agriculture and the advance of soybeans have driven significant growth in several economic sectors directly and indirectly linked to production and has brought a new dynamic to local, regional and national economies in response to growth in international demand and prices. This was very noticeable in the late 1990's and early twenty-first century.

The biodiesel industry in Argentina has exhibited steady growth with soybean production rising 24 times during 2006 to 2011, from 130,000 tons to 3,084,000 tons (Bragachini *et al.* 2011). By 2007 Argentina's biodiesel industry had a large export component, positioning by 2009 as the world's largest exporter and since 2010, when the government introduced the mandatory mixing of biodiesel with diesel fuel (first 5%, then 7%, in September 2011), biodiesel plants took up the challenge of supplying new domestic demand without losing their leading role as exporters (ADIMRA 2012).

1 http://www.argentinarenovables.org/leyes.php
2 http://www.responsiblesoy·org/

Currently, there are over 30 biodiesel processing plants, medium and large-scale, investing more than 900 million dollars in five years. Some of the most important plants are located near the port terminal of Rosario, but there are plants of different sizes in towns and cities across the country, providing employment and value added to the crop (ADIMRA 2012).

The introduction of biofuels as an energy source in Argentina is a momentous decision for its implications on the environmental (reduction of carbon emissions), economic (depletion of fossil fuels compared to continued growth in consumption, the potential of agriculture to offer a proportion of production as an energy source, the generation of alternative employment opportunities and diversification of agri-business, both in the Humid Pampas as well as for regional economies) and strategic levels (promotion of renewable energy sources) (Poledo 2009).

Potential export markets, such as the European Union (EU), offer opportunities for increased trade and therefore economic development: in only one year, biodiesel generated more than 200 million dollars in tariffs (CADER 2009). Another policy objective is that of increasing energy security and diversification. Since the economic crisis in 2001, investment in the oil sector has fallen behind increasing demand and by 2010 Argentina became a net importer of oil. The government is therefore keen to ensure new energy supplies (Lamers 2006, USDA 2010).

Other important factors driving biofuels are pressure from the agricultural sector and differences in export tariffs. To promote the production of value added products, the government has reduced export taxes on such products. Whereas exports of soybean oil are subject to export taxes of 32%, biodiesel produced in Argentina is subject to 14% tax, thus reducing the price of local soybean oil (CADER 2008). While the production of biodiesel incurs an increase in production costs (around 10% for large producers), the difference in export tariffs provides an incentive to produce biodiesel for the export market. In practice, the tax differential is financed by a fall in the incomes of farmers, who receive a lower price for their products (Tomei and Upham 2009).

History of biofuel development in Argentina

The history of biofuels in Argentina began in 1928 with the use of a fuel blend called “Giacosa” (15% petroleum, 5% methylene and 80% alcohol), invented by Luis Giacosa who patented it on October 3, 1927. Years later, in 1942, the governor of Tucumán used a vehicle powered by a fuel that was 30% denatured alcohol and 70% gasoline to travel throughout Argentina to demonstrate its use as a substitute for gasoline. Since the experience was successful, the department of research and development of the state oil company, Yacimientos Petrolíferos Fiscales (YPF), began testing on biofuels. Not until 1979, after many years of research and testing, did the province of Tucumán initiate “Plan Alconafta” which was aimed at promoting the use of ethyl alcohol derived from sugar cane (*Saccharum officinarum*) as fuel. Up until early 1987, 12 provinces made up the plan since alconafta was economically viable because it was subsidized by the state. However, during the following years the sugar harvests were low and not sufficient to cover the necessary consumption of alcohol. Moreover, the international price of sugar rose, leading to the abandonment of the “Plan Alconafta”. There have been several additional attempts to promote the use of biofuels, but the low possibility of receiving economic incentives similar to those for petroleum fuels represented a barrier and discouraged investment in the sector (Scheinkerman de Obschatko y Begenisic 2006).

Considering the passing of the Biofuels Law (Nº 26.093) and faced with the exhaustion of petroleum stocks and rising prices of petroleum and other non-renewable energies, ethanol as alternative energy is encouraged in Argentina. Ethanol is mainly produced from sugar cane whose distilleries are concentrated in northwestern Argentina. In 2010 the country produced 114 million liters of ethanol from six distilleries. Today, the sugar cane-based plants promise the national government to supply 25% more ethanol during 2012 than in 2011. According to Resolution 5/2012 published in the Official Gazette[3], which is signed by the Secretary of Energy, Daniel Cameron, 11 companies –”nine mills and two corn alcohol distilleries”– will produce 260 million liters of ethanol, against 210 million liters promised for 2011. This implies a 23.8% increase in total biofuel produced to replace gasoline.

Biodiesel production in Argentina, mainly from soybean, was only a few years ago undertaken on a small scale. Some plants were operating during the 90’s, but reached very low levels of production. Only since 2004 had production began to grow and has had a steady growth since 2006. Consequently, Argentina ranks third in production capacity of biodiesel worldwide, being the fourth largest producer and the largest exporter of this biofuel by 2010 (Bragachini *et al.* 2011).

In the realm of science and technologory, different institutions in Argentina, such as the Instituto Nacional de Tecnología Agropecuaria (INTA), the Instituto Nacional de Tecnología Industrial (INTI) and the Comisión Nacional de Investigaciones Científicas y Técnicas (CONICET), have undertaken various investigations concerning biofuels, especially directed towards demands from federal agencies such as Secretaría de Energía (SE), Secretaría de Ambiente y Desarrollo Sustentable (SAyDS), Ministerio de Agricultura, Ganadería y Pesca (MAGyP), Ministerio de Ciencia, Tecnología e Innovación Productiva (MCTIP) as well as provincial governments and municipal departments of agriculture. INTA maintains cooperation agreements with international organizations such as the Food and Agriculture Organization (FAO), the Global

3 http://www.eldial.com/nuevo/boletin/2012/BO120130.pdf

Rubén D. Quintana

Field with soy over National Route Nº 9, Buenos Aires.

Environmental Facility (GEF), the United Nations for Industrial Development Organisation (UNIDO), the Instituto Interamericano de Cooperación para la Agricultura (IICA PROCISUR), and the US Environmental Protection Agency (EPA), oriented to meet the demands of industry and society[4].

The investigations being carried out by INTA include energy balances, life cycles, efficiency studies, implementation of Geographic Information Systems (GIS) at regional and national levels, economic and energy evaluation of the production of bioethanol and biodiesel, and the improvement and assessments of crops for ethanol production such as sugar cane (*Saccharum officinarum*), corn (*Zea maiz*), sweet sorghum (*Sorgum bicolor*), sugar beet (*Beta vulgaris*), and switch grass (*Panicum virgatum*) and the Jerusalem artichoke (*Helianthus tuberosus*), safflower (*Carthamus sp.*) and jatropha (*Jatropha curcas*) for biodiesel production[4]. These studies seek to assess the agro-industrial systems that produce biofuels in the country by ecoregion, their energy balances, the use of their products, and correct waste treatment. These studies also establish benchmarks for sustainability and encourage production systems that illustrate effective management of natural resources which also optimize production.

Current national debate about biofuels

There are various and partly totally opposed streams in the national debate regarding the advantages and disadvantages of biofuels, reflecting different perspectives.

On the one side, there is the general trend to support the development of biofuels. This positive view represents also the current perspective of Argentinian policy, which provides enormous incentives for enhancing biofuel production. On the other side, there is a magnitude of reports warning of excessive expectations and of negative effects of uncontrolled rise of biofuel production on the environment and on human health. However, these opinions, analyses and assessments are published mainly in scientific journals not available to the general public.

Argentina has two important national newspapers which address issues related to biofuels. Although not covered on a regular basis, readers are moderately well informed about the current and future importance for the need to use biofuels. The level of knowledge of the readers can be considered good, but it must be emphasized that due to the size of the country, other available media, the level of education and societal behavior there are other important means for the dissemination of information.

[4] http://www.inta.gov.ar/info/bioenergia/bio.htm

The topics covered in articles, general publications, economic and industry sections, agriculture oriented supplements and editorials, invited opinions, and readers' letters contribute to forming public opinion.

The two national newspapers make it known that, according to the Law 26.093 by 2010 national fuel consumption needs to consist of at least 5% biofuels. This is obtained through the existing ability to produce biofuels, the abundance of soybeans and necessity to comply with the law.

An interesting point is that much of the population, mainly the lower income, uses radio (AM and FM) and some local TV channels as their principal source of information. These sources also address the issues related to development, production needs and uses of biofuels, but also cover the topic of climate change and the role that biofuel development will play in it.

In synthesis, information on biofuels is sufficient, disparate, related to other issues (climate change) and produces opportunities for local or regional use of alternative energies.

CHAPTER 3

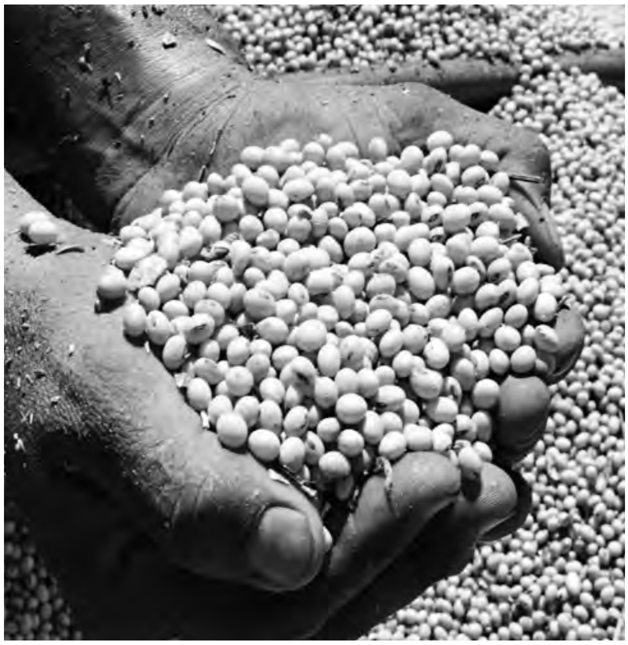
Cultivation of soybean

History of the soybean crop in Argentina

The first sowing of soybean in Argentina was made in 1862, but only in 1925 the Minister of Agriculture introduced soybeans from Europe –known at that time as hairy vetch or "soja híspida"– and promoted its adoption. Up until 1956 the basics aspects of soybean crop were still unknown. During the 1970's, soybean cultivated areas began to expand in Argentina, mainly into the pampas. On August 6, 1971, in the Casilda School of Agriculture, local INTA Rural Extension Agency organized the first meeting on soybean expansion, attended by 120 farmers who shared their experiences. From this meeting evolved the second agricultural revolution in the pampas, the first being wheat production starting in 1860: 770,000 ha were planted with soybean in 1977, increasing to 1.75 million ha in 1978. For a century no such thing had occurred in the pampas. In 1992 the area planted with soybean exceeded that of wheat (*Triticum aestivum*), which was the "civilizing" crop of the pampas. This change marks not only a quantitative difference but a definite modification of the northern pampas, as soybean requires more investment and knowledge than wheat. Many multinational agrochemical companies are established in Argentina, taking advantage of soybean expansion (Martínez 2010, pers. comm. 2012), which increased during 1996-1997, when genetically modified soy was introduced, facilitated by the widespread adoption of minimum tillage sowing (Figure 1).

In addition, this growth benefited from higher production costs of alternative crops such as corn and sunflowers (*Helianthus annuus*) and shorter contracts for soybeans. Since the middle of the 1990´s, soy was primarily grown in crop rotation patterns with wheat and maize, rotations that are still practiced in Argentina. Nevertheless, most often only by farmers which can afford high machinery and seed input. At present, 18,885,000 ha are planted with soybean, representing 61% of the row crop area in Argentina[1].

Increases in crop production can occur from variation of two factors: an improvement in yields or an increased acreage. Increased crop yields, which have still not peaked, are associated with the adoption of new technologies by the agricultural sector, particularly in recent years. The increase in acreage has been at the expense of replacing natural ecosystems such as native forests (Gasparri and Grau 2006) and/or by the displacement of other activities such as livestock and dairy production or other crops. For example, there is a clear relation between the situation of the Parana Delta and the surrounding agricultural landscape. Big-scale livestock farming and changes in land-uses within the region are a direct consequence of the massive expansion of soybean cultivations. Soybean crop was the main driver forcing livestock (around 1,500,000 cows) to move from the pampas to the edge of the Parana Delta and its islands. This scenario includes the construction of embankments, the spraying of agrochemicals and the use of intentional fires (207,000 ha of native vegetation were destroyed by fires in April 2008), which seriously threaten wetlands and organic soils (Blanco and Méndez 2010).


RTRS

Soybeans ready for going to market.

Current land area and trends on soybean-based biodiesel production

According to consultations with specialists (Agustín Mascotena, Executive Director, RTRS), there is presently about 6-8 million tons of soybean used for biodiesel, approximately 14% of the total production of Argentina.

Future scenarios portray Argentina as a principal producer of soybean and biofuels. Available technologies and medium-term policies give confidence to producers and can easily lead to production exceeding 130 million

[1] http://www.siia.gov.ar/

tons of cereals and oilseeds annually. Soy is, and will continue to be, ranked first in area and economic performance, which may increase significantly when production is encouraged for use as a biofuel. This new market will bring higher prices, along with another expansion of soybeans planting and production for export, biofuels and for domestic consumption, mainly in meat production.

For the coming years the global outlook for biofuels will depend on a number of interrelated factors, including petroleum prices, the availability of cheap raw material, the continuity of public policies that encourage the industry, technological changes that could reduce the cost of second-generation biofuels (algae and cellulose), and competition from unconventional fossil fuels (coal, gas and oil shale). On the demand side, several countries are gradually pushing for regulations for the period 2007-2013[2].

Description of areas used for cultivation of soybean crop

Currently, soy farming occupies a large area extending from parallel 23ºS to parallel 39ºS. Within this area, two major production regions could be distinguished (Figure 2), differing significantly in cultivated area (Figure 3A) as well as in soybean production (Figure 3B). These differences are associated with environmental conditions such as soil quality and climate.

Soybeans are grown on soils with moderate levels of organic matter and high levels of fine material such as silt and clay -mostly from loess deposits- with predominantly surface silt loam.

Primary region

The primary region is located in the pampas of central-eastern Argentina, comprising the south of Santa Fe, south-central Córdoba, north-west Buenos Aires and west-central Entre Ríos provinces (Figure 2). This is characterized by agricultural production and the development of soybean cultivation on a large scale (Figure 4).

The primary region accounts for the 90% of the country's total output (Figure 3A). This region of high intensity production coincides with a strip of about 200 km along the west bank of the Parana River, expanding on the east bank, up to its confluence with the La Plata River. Soybean production in this region has increased due to infrastructure, proximity to ports, improvements in yields through the application of technological and/or the displacement of other crops such as cotton (*Gossypium herbaceum*) in the north of Santa Fe and Chaco and corn and sunflowers in the north and southwest of Buenos Aires.

In this region the area cultivated in soybean varies between 25% and 75% (Figure 2). Departments with the greatest soybean areas are in Buenos Aires: Leandro N. Alem (72.6%), Captain Sarmiento (69.0%), General Arenales (67.3%) and Salto (65.6%); in Córdoba: Marcos Juarez (68.2%) and Río Segundo (59.8%); and in Santa Fe: Constitución (71.0%), Caseros (69.3%), Rosario (66.1%) and San Lorenzo (64.2%).

The climate is mild with an average annual temperature of 17º C and average annual rainfall of >900 mm, with regional variations due the proximity to the ocean and differences in topography. This region corresponds to pampean sub-regions known as the Rolling and Inland Pampas. 42% of soils are suitable for agriculture and land holdings are small to medium in size (50 to 300 ha), with well developed infrastructures. Agriculture is the predominant economic activity and increases annually due to the presence of *contratistas*, transitory contractors with the machinery for seeding and harvesting medium to large areas.

Secondary region

The adaptation of soybean to different environmental conditions, due in part to their low demands and "plasticity" (does not need soil rich in nutrients, is carried out in neutral or slightly acidic soil, does not require much water, it is tolerant to certain salinity levels, etc.), has allowed its expansion to less productive and more fragile extra-pampean regions (Figure 2). Thus, the secondary region extends from the provinces of Chaco, Salta and Tucumán in the north, to San Luis, north La Pampa and south-central province of Buenos Aires.

Soybean expansion in the north of Argentina has been possible mainly due to the conversion of native forest (Figure 5) and displacement of extensive livestock production. Subsequently, the agriculture matrix has becoming increasingly predominant over forest remnants, differing in their degree of human disturbance and vegetative succession (Bertonati and Corcuera 2000). This zone is a plain with little relief except for a weak slope in northwest-southeast direction, indicated by the direction of parallel rivers that flow through the territory. The three major rivers running through the region (Pilcomayo, Bermejo and Salado) receive water from tributaries for 600 km from their origin in the Andes, leaving much of its waters in wetlands, and are not navigable except the Bermejo in its final downstream section.

The northern part of the secondary region can be separated into two areas considering precipitation: the east with rainfall of >1,000 mm annually throughout the year, although higher in summer, and the west, with a winter dry period up to eight months. Vegetation varies accordingly, with forest supporting economic valuable species, as *quebracho* (*Schinopsis* spp.), *cedro* (*Cedrela odorata*) o *lapacho* (*Tabebuia* spp.) predominating in the

[2] http://www.ers.usda.gov/AmberWaves/November07/Features/Biofuels.htm


RTRS

Soybean harvest.

northeast on sandy-clay soils, interspersed by clearings on saline or hydric soils. Colonization over areas where the forest has been cleared is only by palms, such as *pindó* (*Syagrus romanzoffiana*) and *yatay* (*Butia yatay*), which are associated to grazing lands, known as "*abras*". Towards the west, the semi-humid Chaco forest is interrupted by extensive open fields covered with grasses and prickly vegetation. More westward, as precipitation decreases, the presence of cactus is more common and forms impenetrable thickets in clearings. The predominant tree species is quebracho, which exploitation has caused the destruction of natural forest, with no regeneration, with consequent advance of desertification in areas where environmental conditions are not conducive for agriculture. The population is partly formed by indigenous groups; main urban centers are located in the highlands or ridges over the shores of the Paraguay and Parana rivers and where Salado and Dulce rivers cross in Santiago del Estero, known as "diagonal fluvial". Resistencia, capital of Chaco province, is the major city in this area and has a natural exit to the Parana River, the port of Barranqueras[3].

In areas such as the Flooding, central area of Buenos Aires province, soybean production is more recent, replacing livestock during drought periods with consequent loss of pastures (mostly semi-natural).
In the secondary region of soybean production, planted area generally does not exceed 25% of the territory, although some municipalities have >25% of their area under cultivation. For example, Chacabuco (48.5%; Chaco), General Belgrano (39.7%; Chaco), Cruz Alta (34.8%; Tucumán), La Cocha (34.3%; Tucumán), Necochea (34.0%; Buenos Aires), Tandil (33.3%; Buenos Aires), Burruyacú (30.2%; Tucumán), Belgrano (29.9%; Santiago del Estero), Salliqueló (29.7%; Buenos Aires), Uruguay (28.4%; Entre Ríos) and General Taboada (27.9%;Santiago del Estero).

Land tenure systems in soybean areas

The economies of scale inherent to the new production system of soybeans, as well as the many economic crises that have plagued the country, have led to the concentration of land ownership. In the 1990´s, state policies favored large producers, defining farms smaller than 200 ha as 'uneconomical'. From 1992 to 2002, an estimated 60,000 small producers left agriculture (Joensen *et al.* 2005). During 2007, 60% of soybean harvest was produced by just 4% of farmers. In addition, high international price of soybean and its profitability has led to a rise in tenant farming and absentee landlords (Tomei and Upham 2009). Farmers who are unwilling or no longer able to take the production risk

3 http://www.todo-argentina.net/geografia/argentina/reg_chaco_e.htm).

rent out their land to others (neighbors, contractors or investment trusts), who manage production from year to year. As a result, the value of land has increased five times in the past decade (Monti 2008), and in 2007 some 60% of farms were managed by tenants. The process has inevitably led to a loss of traditional and cultural knowledge which is irreversible.

The concentration of rural enterprises will continue to occur due to the need to adapt to short-term policies and other uncertainties, conditions where small and medium farmers are not financially able to reinvest in technology and modernize their businesses, and subsequently choose to rent or sell their properties. Between 1969 and 1988 the process of land concentration presented an annual trend of about a -1.35% change in the number of enterprises, while during 1988 to 2002 the process accelerated to -1.65%. During 1988 to 2002 the number of rural enterprises reduced from 538,000 to 333,000 and it is estimated that with the continued dominance of row crop agriculture and the formation of groups who rent land (cooperatives, *pool de siembra*, and trusts), this trend will accelerate.

This situation of land tenure concentration can be analyzed from various perspectives, the main ones being productive, social and economic. The concentration of land in few hands or companies could bring economic improvement and production but also concentrate profits for those few while reducing local expenditures and investments since the process depends on inputs from major commercial centers rather than local towns. The handling and application of modern technology can bring both increased production and conservation of natural resources when production is planned over the long term, or for those who rent annually or over the very short-term, or for crops where production and income are maximized by ignoring the environmental conservation or social aspects. Between these extremes lies a vast range of situations permitted by legislation or the lack of law enforcement.

Description of cultivation systems

Production techniques

Land preparation for soybean planting has evolved in recent decades from a traditional system of soil tillage to no-till sowing. Over 80% of soybean planting, both first and second plantings (following wheat), are done using no-till and seeds inoculated with nitrogen-fixing bacteria (Pognante *et al.* 2011).

The time of sowing, carried out between August and February, depends on the area of cultivation, the preceding crop, and the availability and costs of seeds. Seeds are sown in rows spaced 45-60 cm apart and range between 45-50 plants per square meter (450,000-500,000 plants/ha). The density varies with soil, climate and plant variety and if the crop is rain fed or irrigated (García et al. 2009).

Using no-till, weed control is achieved by chemical treatment and the near total adoption of glyphosate-resistant varieties of soybeans has determined that glyphosate is the most widely used herbicide. However, there are alternative products for different conditions (type and amount of weeds), which can complement the application of glyphosate (Garcia *et al.* 2009).

Fertilization of soybean is important in order to get best yields. The main fertilizer used in soybean production is the single superphosphate, also known as starter fertilizer because it is applied during sowing providing required levels of phosphorus, sulfur and calcium. Application rates range between 50 and 100 kg/ha but the amounts vary depending on soil type and previous crop (García 2009). For example, in the southeast of Buenos Aires province almost no nitrogen fertilizers are used (only inoculants) and approximately 80 kg of diammonium phosphate (DAP) or triple superphosphate equivalent are applied to about 16 kg of phosphorus; in this cases a small amount of nitrogen is applied (approx. 13 kg/ha).

Soybean is very drought resistant, particularly compared with other pampas' crops. It needs moisture but not flooding, since this suffocates the plant roots. For this reason it does not require copious amounts of irrigation but must maintain slight soil moisture. Due to soil and climatic conditions, the need for irrigation of soybean in the primary region is negligible.

Soybean is the second crop affected by pests –mainly insects– after cotton, which cultivation occurs in the north of Argentina. Due to this, soybean requires more insecticides than cereals (corn, wheat) or other oilseed crops (sunflower, rapeseed). Soy is attacked by a great diversity of species of defoliating caterpillars (Lepidoptera: Noctuidae) during the growing season, whereas during the fruiting stage increases populations of *chinches* (Hemiptera: Pentatomidae), insects that pose a serious threat to the crop for its large effect on yield and seed quality. Because of early planting, soybean is also attacked by molluscs (slugs and snails) and crustaceans (*bicho bolita*), and other pests like cutworms, which can cause severe crop damage early in the growth cycle. During the 2001/2002 season, attacks of *chinches* (*Nezara viridula* L. and *Piezodorus guildinii* West.) increased and in some cases led to total losses in some fields and high levels of damaged grains and low yields in others (Aragon 2002).

Soybean yields depend on the variety used, soil type, crop management, weather, and its planting in quality environments and under good management can produce more than 4,500 kg/ha. Several factors may adversely affect yields and major diseases that attack the crop are the "end-of-cycle" diseases (EFC) and the Asian rust (RAS), whereas other diseases attack the stem and roots. The main strategies against EFC include the use of tolerant cultivars, seed treatments, management practices (crop rotation, planting dates, fertilization), and foliar application of fungicides. To control RAS, management measures include planting in short cycles, elimination of *plantas guachas*, systematic monitoring and chemical control using fungicides (Garcia *et al.* 2009).

Of note is the enormous advance in precision agriculture occurring in Argentina in recent years aiming to achieve an efficient management of the variety of interacting factors influencing crop yield in different environments within a farm (Bragachini 2010.) The Precision Farming Project of INTA functions in close association with the private sector, suppliers, technical leaders in precision agriculture and institutions such as Aapresid, Consorcio Regional de Experimentación Agrícola (CREA) and Instituto de la Potasa y el Fósforo (INPOFOS). This project directs its efforts towards overcoming specific problems in production systems, under the concept of achieving gains in productivity through more and better data collection, improved methodologies for analysis and diagnosis, tending in the medium term to site-specific management of crops and soils (http://cdi.mecon.gov.ar/biblio / docelec/dp3562.pdf). The possibility of geo-referenced agronomic data management offered by this technology is already providing concrete benefits in Argentina. Producers manage maps of yield, and undertake correct trial designs of management factors across the natural and induced sources of variability in large lots, and manage costs more precisely and efficiently than other producers who lack such technical information (Bragachini 2010).

RTRS

Agrochemical application.

Principal agrochemicals

As already mentioned, no-till is the main production system used in soybean cultivation. This technology is strongly associated with the use of the herbicide glyphosate, along with insecticides cypermethrin and chlorpyriphos, varying with management, culture rotation and the type of pest. Some characteristics of the main agrochemicals used in soybean production are presented below.

Glyphosate

Glyphosate, the principal herbicide used in the production of soybean due to crop resistance to the chemical, is a systemic, non-selective, broad spectrum herbicide which affects post-emergents and is, used to control annual and perennial graminoides, broadleaf weeds and woody species. Glyphosate is an acid, but is commonly used in salt form, most commonly as isopropylamine salt of glyphosate or isopropylamine salt of N-(phosphonomethyl) glycine (Nandula *et al.* 2005). Pure glyphosate is a crystalline solid with high water solubility (12 g/L) (Franz *et al.* 1997) and very low vapor pressure ($5.7x10^{-8}$ Pa at 25ºC) (Battaglin *et al.* 2005). From a human health perspective, glyphosate is classified as carcinogenic category D because of evidence of non-carcinogenicity for humans (EPA 1993).

Glyphosate inhibits the biosynthesis of aromatic amino acids (phenylalanine, tyrosine and tryptophan) such as the enzyme 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase (Franz *et al.* 1997). It can also suppress the action of two enzymes, chorismate mutase and prephenate dehydratase, involved in other steps in the synthesis of these amino acids. All these enzymes are part of the chemical acid pathway present in higher plants and microorganisms but not in animals (Franz *et al.* 1997). The mean half-life of glyphosate in soil has been reported as 32 days in forests and row crops but varies considerably as a function of microbial activity, soil pH, and temperature (Giesy *et al.* 2000, Chang *et al.* 2011). In the environment, glyphosate is degraded to aminomethylphosphonic acid (AMPA). The half-life of AMPA is largely unknown but is thought to be greater than that of glyphosate, because it has been observed to accumulate in soil. Both glyphosate and AMPA have been detected in natural waters near agricultural areas (Chang *et al.* 2011).

Glyphosate is very soluble in water, remaining in the ionic state and adhering to particles. This gives glyphosate high stability and transport capacity while assuring retention in aquatic ecosystems. It persists in ponds from 12 to 60 days and has a half-life in sediments of up to 120 days (IPCS 1994).

Glyphosate, being water soluble, does not cross lipid membranes such as skin, so products require surfactants that act as carriers to penetrate plants and animals. These products, such as Polyethylenediamine (POEA), also have their own toxicity and exacerbate the effect of herbicides (Bradberry *et al.* 2004). There is insufficient evidence to conclude that glyphosate preparations containing POEA are more toxic than those containing alternative surfactants. Although surfactants probably contribute to the acute toxicity of glyphosate formulations, the weight of evidence is against surfactants potentiating its toxicity (Bradberry *et al.* 2004).

Cypermethrin

Cypermethrin is the principal insecticide applied to soybeans. It is a natural insecticide, but this pyrethroid has been modified to make it persistent in the environment with much higher biological activity than its natural form. Evidence suggests that after application to crops, residues can be found in soils, surface water and sediments, but biodegrades relatively quickly and its residues do not remain in the environment for a prolonged period. Despite the influence of various factors, it is considered that the half-life in soil under aerobic conditions is 4 days to 8 weeks and in water it is greater than 50 days (Maund *et al.* 2002).

Cypermethrin eliminates *Coleoptera* and *Lepidoptera* and can be applied by land or air. A frequent practice is to apply cypermethrin and other pyrethroids too early at the beginning of the growth cycle ("pyrethroid jet") accompanying the application of glyphosate. The belief that persistence in the system has a protective effect has helped to promote the mass adoption of this unnecessary practice, mainly in the south of Santa Fe, regularly with the use of glyphosate during the development of soybean and on treatment of chemical fallows prior to planting (Massaro 2010).

Chlorpyrifos

Chlorpyrifos is an organophosphorus compound that displays broad-spectrum insecticidal activity against a number of important arthropod pests. Various formulations of chlorpyrifos have been developed to maximize stability and contact with pests and minimize human exposure. Due to the nonpolar nature of the chlorpyrifos molecule, it possesses a low water solubility (< 2 ppm) and great tendency to partition from aqueous into organic phases in the environment (log P of 4.7-5.3). It is characterized by an average soil and sediment sorption coefficient (Koc) of 8,498 and aquatic bioconcentration factor of 100-5,100 in fish. As a result of this high propensity for adsorption, its movement through and over the soil profile is limited. Surface runoff and erosion mobility are also low, and, in general, less than 0.3% of soil surface application. Chlorpyrifos is a degradable compound, and both abiotic and biotic transformation processes affect its degradation within environmental compartments (Racke 1993).

Endosulfan

Endosulfan is an organochlorine chemical which affects insects through contact and ingestion. It was banned in Argentina in 2011 by the National Service of Agrifood Health and Quality (SENASA) based on international and national recommendations which promote the progressive suspension of its use for pest control in crops. SENASA banned as of July 1, 2012, the import of the active ingredient in formulated products and from July 1, 2013, the development, formulation, marketing and use of products containing the active ingredient.

CHAPTER 4

Impacts on wetlands

Wetlands ecosystems in Argentina

Estimated wetlands area in Argentina is about 600,000 km^2 (Kandus *et al.* 2008), representing 21.5% of the national territory; an area that increases to 23% when considering salt lakes and deepwater bodies. Large wetland areas are mainly located in the humid north-eastern region of the country, associated with the Chaco-Pampeana Plain (e.g. *Bajos Submeridionales* and Flooding Pampa) and the rivers of La Plata Basin (Figure 6), while in the rest of the country wetlands are mainly located at particular sites, such as river valleys, depressions and at the foot of hills or mountains (Kandus *et al.* 2008).

Among the six main wetland regions of Argentina (Canevari *et al.* 1999; Figure 6), La Plata Basin and Chaco regions, in the northeast of the country, have a remarkable abundance of wetlands associated primarily with the basins of the Paraguay, Pilcomayo, Bermejo, Paraná and Uruguay rivers. The Pampas region characterizes by a great variety of freshwater marshes and open lagoons, as well as by tidal marshes associated to particular estuarine ecosystems along the Atlantic coast. On the other hand, Patagonia and the Andes are arid regions where wetlands are more scarce and restricted in their distribution, playing an important role in providing water and forage for livestock and habitat for biodiversity.

As previously described, the distribution of soybean in Argentina mainly covers the central-eastern region of the country north of Patagonia (Figure 2), overlapping with the highest concentration and area of wetlands in the country (Figure 6). In particular, with wetlands located in the Chaco and Pampas regions; to a lesser extent with La Plata Basin and only marginally in the north of Patagonia.

Coastal Lagoon, San Cayetano, Buenos Aires.

Daniel E. Blanco

Primary region

The primary region of soybean production (soybean core) (Figure 2) includes several lakes and wetlands systems associated to edaphic restrictions, such as flooding, limited drainage, etc. (Kandus *et al.* 2008) (Figure 6), comprising 10 wetland sites of conservation significance (Scott and Carbonell 1986), such as Laguna Mar Chiquita, Laguna Ludueña, Lagunas de Etruria, Bañados de Rio Saladillo and Laguna La Margarita in Córdoba province and Laguna Melincué in Santa Fe province. In the north of Buenos Aires province some important wetlands systems are also found: the lake system Las Tunas-El Hinojo and wetlands in the municipality of 9 de Julio (Gomez and Toresani 1999).

In this region, two Ramsar Sites are also found[1]:1) Bañados del Río Dulce y Laguna de Mar Chiquita (Córdoba province) and 2) Humedal Laguna Melincué (Santa Fe province).

1) **Bañados del Río Dulce y Laguna de Mar Chiquita** (Córdoba province) is considered one of the most important wetlands in Argentina and the Chaco ecoregion, due to their richness of biodiversity, which includes a minimum of 30 waterbird species and 27 fish species that breed in the area. The predominant land use in the north and west of the area is extensive livestock grazing, while towards west, where soil characteristics are less constraining, there are incursions of the eastern Chaco forest so logging and charcoal production are practiced. Towards the southern and eastern limits land use is mixed: agriculture (soy, wheat, corn, sunflower, etc.), livestock (cattle) and dairy (on alfalfa and oat pasture). Additionally, there are urban areas and agro-industrial establishments.

Ramsar Site Bañados del Río Dulce y Laguna de Mar Chiquita.

Jorgelina Oddi

Marcelo Romano

Ramsar Site Laguna Melincué, Santa Fe.

2) **Humedal Laguna Melincué** (Santa Fe province) and its watershed represent one of the most important lentic systems in Santa Fe province. Immersed in a mainly agricultural and livestock region, this wetland is of regional and continental significance as it represents an important habitat for resident and migrant birds. The whole system forms an almost rectangular endorreic basin about 50 km wide, with the main area of open water exceeding 120 km^2; hydrographically, is the final destination of water from wetlands and temporarily flooded areas. The terrestrial environments, dominated by pampean grasslands ("flechillar": grassland community with two layers, the higher composed mainly of *Stipa* spp., *Paspalum* spp. and *Panicum* spp. and the lowest composed of many dicotyledons), have been almost completely converted to cropland and pasture of introduced species, while the aquatic environments and the terrestrial habitats most directly associated with them, are more intact given the inherent difficulties associated with converting them for agricultural production. Farming is undertaken on higher lands in the surroundings of the lagoon, mainly includes wheat, soybean, maize and sorghum. There is a trend in the region towards the increasing industrialization of agriculture, mostly towards soybean monocultures. Row crops production, however, is limited by altitudinal gradients, where conditions are increasingly unsuitable for agriculture at the lower extent of the elevation gradient near bodies of water and are generally utilized for livestock production[2].

Secondary region

The secondary region of soybean cultivation (Figura 2) includes numerous wetland systems (Kandus *et al.* 2008; Figure 6) of particular conservation interest and value. These include Bañados del Quirquincho (Salta province), Bajos Submeridionales (Santa Fe province),

[1] http://www.ambiente.gov.ar

[2] Ramsar Information Sheet Humedal Laguna Melincué: http://www.ambiente.gov.ar

Bañados de Figueroa (Santiago del Estero province), Salinas Grandes (shared by Catamarca, Córdoba, La Rioja and Santiago del Estero provinces), Guanacache and Rosario lake systems (shared by Mendoza, San Juan and San Luis provinces), Albufera Mar Chiquita, Western chain lakes and the wetlands of Chascomús (all in Buenos Aires province) (Scott y Carbonell 1986, Bucher y Chani 1999, Gómez y Toresani 1999).

Four Ramsar Sites are also found in this region[3]: 1) Bahía Samborombón, 2) Jaaukanigás, 3) Chaco wetlands and 4) Palmar Yatay. These systems, however, are only marginally located in areas of soybean production.

1) **Bahía Samborombón** (Buenos Aires province) extends over 180 km of coastline, being the largest mixohaline wetland in Argentina. It is an extensive intertidal zone, characterized by mudflats and salt and freshwater marshes. The tidal influence causes influxes of salt water while rivers, canals and streams contain freshwater, determining a complex hydrological system subjected to these flows, creating a variety of wetlands. One of the most important reasons for its designation as a Ramsar Site is its value as habitat for migratory birds, since it is estimated that more than 100,000 plovers and shorebirds (Charadriidae and Scolopacidae families) make use of the bay. It is also an important spawning area for commercially important fish species. Soil constraints such as salinity and flooding results in the area having a very low agricultural potential that has slowed the progress of soybean expansion in the region[4].

2) **Jaaukanigaas** (Santa Fe province) covers part of the middle Parana River floodplain, consisting of a vast complex of rivers, lakes, dry river beds, seasonally flooded grasslands, riparian forests and islands. The site is characterized by a remarkable aquatic biodiversity, with around 300 fish species that are key to the regional economy, since 50% of the population of the area is depends upon fishing as their source of income. Soils bordering the site are mostly well drained and suitable for agriculture, covering over 45,000 ha, where soybean, sugarcane, sunflower, cotton and wheat and cultivated[5].

3) **Humedales Chaco** (Chaco province) are generally oriented in a northeast-southwest direction along the axis of the Parana and Paraguay rivers. Within the biogeographic region of eastern Humid Chaco, includes the floodplains of the Parana and Paraguay rivers, plus numerous tributaries like the Bermejo, Negro and Salado. Through this network of tributaries an active flow of floral and faunal elements occurs. This system serves as a refuge for micro and mesofauna associated with aquatic environments during periods of severe drought. Within the site soybean crops are grown on a small scale, but it supports about 5,000 ha of intensive soybean cultivation in its surroundings[6].

4) **Palmar Yatay** (Entre Ríos province) is located at the boundary between Pampa and Espinal ecoregions and subsequently it shares floral and faunal components of both regions. The principal wetland types are the gallery forests along the banks of rivers and streams, flooded depressions and temporary ponds formed during the rainy season. These wetlands are embedded in a matrix of crops and forest environments and palm savannas and xerophytic grassland[7].

Daniel E. Blanco

Ramsar Site Bahía Samborombón, Buenos Aires.

Impacts on wetlands

The most significant direct effects of the expansion of soybean cultivation are the loss and degradation of natural ecosystems, with a high rate of deforestation in northern Argentina (Grau *et al.* 2005, Altieri and Pengue 2006). The loss of natural ecosystems has caused not only the consequent loss of biodiversity, but also soil erosion and salinization, increasing the water table and risk of flooding due to higher runoff (Jobággi and Santoni 2006). These processes can affect wetlands in areas near or even distant from the source of the problem, sometimes disturbing key wetland systems and Ramsar Sites.

[3] http://www.ambiente.gov.ar

[4, 5, 6 y 7] Ramsar Information Sheets: http://www.ambiente.gov.ar

In the Bahía Samborombón Ramsar Site (Buenos Aires) are the mouths of the Salado and Samborombón rivers, as well as numerous canals transporting agrochemicals and contaminants from inland agricultural zones which ultimately affect the integrity of the ecosystem[8].

In many areas, agricultural expansion has also occurred to the detriment of grazing and other agricultural crops, leading to landscape homogenization and the loss of biodiversity associated with agricultural mosaics or mixed land uses (Zaccagnini and Calamari 2001). Reduced agricultural diversity is also an indicator of environmental degradation, as not only biodiversity and ecological processes associated to heterogenic landscapes are negatively affected, but also diversity of crops (Altieri 1999, Thrupp 2000, Weyland *et al.* 2008).

Soil and water contamination by agrochemicals and direct and indirect effects on biodiversity are some of the negative impacts of soybean monoculture. One of the direct consequences of large-scale agriculture is aerial application of herbicides which results in the treatment of margin fields and semi-natural areas of agricultural landscape (CONICET 2009). Unfortunately, it is very difficult to quantify the effects of chemical products on natural ecosystems. One reason is insufficient funding for field and laboratory research, and also much of the research is over the short-term and can´t be reliably generalized or extrapolated over the long-term. Following are some of the most relevant studies conducted mainly in Argentina in relation to impacts of soybean cultivation on wetland ecosystems and their resources.

Wetland distribution and abundance

A process of wetland loss as a result of agricultural expansion, particularly soybean production, has occurred throughout the primary region, particularly in the southeast of Córdoba province (Quiros *et al.*, 2005, P. Brandolin *et al.* 2012, F. Salvucci pers. comm.).

The southeast of Córdoba was characterized by the abundance of lakes where the predominant economic activity was grazing, mainly for milk production. In 2000 began the construction of large-scale pipelines designed to drain wetlands (P. Brandolin pers. comm.), resulting in the loss of 12% of the region lakes and a 14.7% decrease in flooded areas; while in the western sector of the region, wetland loss reached 42% (Brandolin *et al.* 2012).

An emblematic case is the Bañados del Río Saladillo, one of the most biodiverse sites in Córdoba province, where 69% of wetlands surface and 19.6% of the lagoons were lost (Brandolin *et al.* 2012). This led to the loss of the original connectivity among wetlands and lower species richness and abundance. An important indirect impact is salinisation of surrounding fields by windblown salts and inadequate use of agrochemicals.

Wetland ecosystems located in the southwest of the province of Buenos Aires, within the secondary region of soybean production, are also being altered (Booman *et al.* 2012). Using a time series of satellite images (1998-2006) for the Mar Chiquita watershed, this authors found an alarming degree of modification, with almost 200 small wetlands (1,800m^2 of total area) traversed by channels for drainage and 17% of the streams already channelized.

Loss of Laguna Larga

The Laguna Larga or Laguna de Cachicoya, in Río Segundo, provincie of Córdoba, was originally 110 ha in area, and supported important social and recreational activities such as fishing, boating, and other aquatic activities. Nowadays, as a result of drainage for agricultural purposes, the lagoon has been reduced to three canals, and represents a paradigm of wetland loss in the province of Córdoba (Salvucci, pers. comm.).

Fernando Salvucci

Laguna Larga, Córdoba.

[8] Bahía Samborombón Ramsar Information Sheet: http://www.ambiente.gov.ar

Available information about the impacts of soybean expansion on wetlands in the secondary region is scarce. In the wetlands of *Bajos Submeridionales* (Santa Fe province), the main economic activity is cattle ranching on natural grasslands, while environmental characteristics of the region naturally limits the expansion of the agricultural frontier. Although this wetland system is not in the area of primary production, indirect effects from soybean cultivation in surrounding areas may affect it, since this system serves as an immense repository for water, and is of great importance in the dynamics of the Salado River, since in times of abundant precipitation it overflows there. However, virtually no studies on the effects generated by agricultural activity on the functioning of this wetland system have been undertaken (FVSA and FUNDAPAZ 2007).

Recently, soybean production has been aided through embankment construction in areas such as the delta of the Parana River. These embankments artificially replicate terrestrial conditions for soybean cultivation and directly impact on loss of hydrological functions and ecosystem services provided by wetlands (Blanco and Méndez 2010).

An important impact associated with the loss and degradation of wetlands is the emission of GHG. Biofuels have been promoted as a promising alternative to mitigate climate change. Most prior studies have found that substituting gasoline with biofuels will reduce GHG because biofuels capture carbon through the growth of feedstock (Searchinger *et al.* 2008). However, many reports question the rationale that biofuels substantially reduce carbon emissions (Koh and Ghazoul 2008) and point out the significant biases in estimating GHG balances of biofuels stemming from modeling choices about system definition and boundaries, functional unit, reference systems and allocation methods (Gnansounou *et al.* 2009). Most of the analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest, wetlands and grassland to new cropland to replace the grain (or cropland) diverted to biofuels (Searchinger *et al.* 2008). Regarding soybean, its expansion has contributed to deforestation either directly (soybean planting in natural habitats) or indirectly (crop substitution), in both cases contributing to the expansion of the agricultural frontier (Catacora-Vargas *et al.* 2012).

Accordind to Panichelli *et al.* (2009), land provision through deforestation for soybean cultivation is the most impacting factor of the biodiesel pathway for the global warming potential. Regarding wetlands, there are no studies in Argentina analyzing the balance of GHG by its conversion to agricultural land. However, wetland conversion entails the risk of the emission of high levels of GHG from the carbon they store[9] (Ramsar 2008). Furthermore, as a result of this advance of the agricultural frontier (Ortega and Azcuy Ameghino 2009) livestock is being moved to marginal lands, with serious consequences over the balance of GHG due to practices of burning grasslands to improve forage. Fires in dry conditions generate losses of carbon and nitrogen in soils, since they emit large amounts of carbon dioxide into the atmosphere. For grassland islands of the Delta of Parana river it was estimated that, given the productivity of their reeds, it would require around 11 years to replenish the carbon dioxide emitted by fires occurred in 2008 (Kandus *et al.* 2009).

Ecosystem services

The alteration and, eventually, the loss of wetlands are usually accompanied by the loss of ecosystem functions that provide tangible and intangible benefits of relevance to society (ecosystem services) (Ansink *et al.* 2008; Kandus *et al.* 2011). Some examples of ecosystem services wetlands offer are: storage of organic carbon in the soil, moderating variations in temperature, sources of water vapor for rainfall, reducing the impact of storm surges and navigation, reducing effect of flooding and erosion by attenuating peak current velocity, increasing surplus water storage, retention and fixation of sediment and pollutants, regulation of soil salinity, freshwater for human consumption, supply water and fodder for extensive cattle production, habitats critical to maintaining viable populations of species with commercial and conservation interest, and providing livelihood for local people.

There is a large and growing consensus worldwide regarding the critical economic, social and environmental importance of wetland ecosystems despite representing only 5% of the land surface. Costanza *et al.* (1997) estimated that the overall total value of services provided by coastal and inland wetlands amounted to 17.5 trillion dollars per year, representing 52% of the total value of services provided by all ecosystems on the planet. In turn, during the VIII Conference of the Ramsar Contracting Parties in Valencia during 2002, it was recognized that wetlands play an important role in the sustainability of agricultural activities by providing protection from floods and storms, maintaining water for irrigation, and providing habitat for species that make up significant resources to local communities (Kandus *et al.* 2011).

Within the indirect effects of soybean monocultures are those related to shifting of livestock to marginal lands. In the case of the delta of the Parana River, loss of vegetative cover due to frequent fires set to improve forage quality implies a decrease in flood resistance until the vegetation recovers. The consequence, at least temporarily, is the loss of one of the principal functions of wetlands in the region, via their capacity to buffer hydraulic conditions during flood events.

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9 http://www.wetlands.org

Expansion of soybean cultivation over the Parana Delta region

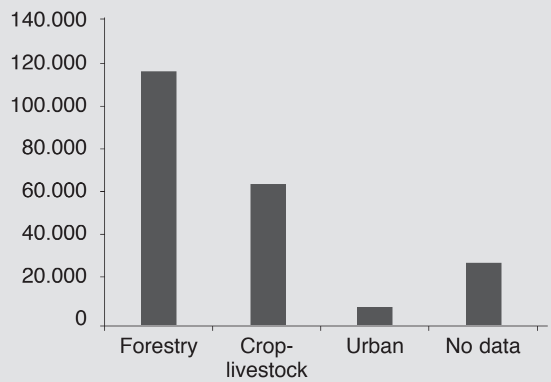
Embankment for agriculture in the Parana Delta.

Parana Delta soils are frequently flooded and poorly drained so their productivity is considered low to very low, and are classified as not suitable for agricultural activities but exclusively fit for uses such as grazing, forestry and wildlife conservation (Gómez *et al.* 2006, Engler *et al.* 2008, Goveto *et al.* (comp.) 2008). Given these restrictions, most of the productive projects need to build dikes and embankments in order to avoid water entrance during river rises (Blanco and Méndez 2010). In a survey during 2010, 875 km of dikes and 202 embanked areas were registered in the Parana Delta region, representing 11.6% of the total area (Kandus and Minotti 2010). The same study reported that 59% of these embankments are used for willow and poplar forestry (forestry core) and that 14% are for agricultural and livestock uses, including soy production.

Since the controversial 12,000 ha embankment illegally built facing Villa Constitución in the Santa Fe province in 2007, where nowadays wheat and soy are cultivated (D. Rodríguez pers. comm.), the trend has been an increase in the embanked area in many Delta towns. These areas are used for agriculture in general and particularly soybean production, including Barbé island facing San Pedro (E. Sierra pers. comm.), Lechiguanas island (E. Sierra pers. comm.) and the south of the Entre Ríos Delta (R. Quintana pers. comm.).

In general, large scale soybean cultivation in the Delta region leads to the *pampeanización*[10] of this region as well as to streams´ obstruction and use of agrochemicals. Some of the impacts associated with soybean cultivation in the Parana Delta are (Blanco and Méndez 2010):

- change in the hydrological regime characteristic of this system as a result of embankments,
- drainage of the islands for agriculture, with the subsequent complete elimination of the low-lands and scrublands located at the center of the islands,
- wetlands connectivity reduced, eliminating fishes´ possibility of using different water bodies, directly affecting fisheries,
- water courses alteration, detrimental to local people displacement and livelihoods,
- loss and replacement of the original plant cover, drastically altering the ecosystem, and the decrease, direct or indirect, of local biodiversity,
- direct impact on the local livelihoods, undermining traditional productive activities such as fishing, apiculture, islands farming or native plants recollection,
- water contamination by agrochemicals, and
- agrochemicals direct effect over apiculture by beehives death, as well as indirect, because honey production is based on native flora adapted to this wetlands dynamic.



Distribution of embanked areas (ha) sorted by main productive activity.

[10] *Pampeanización* refers to a process where an area which does not correspond to the pampas is transformed in such a way that ends having some characteristics of this ecoregion.

Soil health

The term soil health refers to the continuing ability of the soil to function as a living system in natural balance with the environment and land use, sustaining biological productivity, maintaining air and water quality, and promoting plants, animals and people health. Soil health is nothing new, but the names used, the approach given as well as studies and assessments related, have changed and been perfected over time. Since the beginning of the last century, there have been warnings for the need to protect organic matter and soil integrity so that they are not washed away or "blown away by the wind"[11]. With *agriculturization*, mainly in the pampas region, this risk has intensified so that the degradation of this natural resource is today causing serious problems of a different nature such as loss of nutrients, acidification, erosion, compaction and contamination (Culasso and De Carli 2001).

A production system without replenishment of nutrients which lacks from a natural mechanism for replenishment is opposed to the concept of sustainability developed in recent decades, as it would lead to a growing impoverishment of soil nutrients, progressively limiting yields up to the extreme situation where plant growth would be prevented. Some local history illustrates this regional limitation for alfalfa and soybeans in particular (Vázquez 2005; Cruzate and Casas 2012). The total removal of nutrients during the 2010/2011 growing season for the most important crops (soybeans, wheat, corn, sunflower, sorghum and rice) in relation to the 2006/07 growing season increased by 11% due to the increase in production, increased plantings and higher yields (Cruzate and Casas 2012). Within the province of Buenos Aires, the highest removal rates of nutrients occured in the primary production area (north of Buenos Aires, south of Santa Fe and southeast of Córdoba) and in the center and north of the Cordoba province. Soy is the crop with the greatest extraction of nutrients per ton of grain produced, expressed as nitrogen, potassium, calcium and sulfur, and ranking second in phosphorus, slightly surpassed by sunflower. Soybean is the largest extractor of nutrients when measured in tons during the 2006/07 growing season and it is estimated that only 34% of the total nutrients extracted are replenished (Cruzate and Casas 2009).

The lack of nutrient replenishment (approximately 30% of the total extracted in the case of soybean) and the high level of basis extraction by crops are increasing soils susceptibility to acidification (Cruzate and Casas 2003). In Argiudoll, Rafaela Series soils, those under continuous cultivation for over 20 years had a pH=5.6, compared to virgin topsoil with a pH=6.7 (Panigatti 1976). This increased acidity corresponds to lower values of calcium and magnesium mainly, but not potassium, which is enhanced, attributable to its recycling from crop stubble.

The intensification of agricultural production without the appropriate rotations, especially in recent years, has led to decreasing soil quality (Figures 7A and B). Soybean stubble provides little nitrogen, decomposes rapidly, and leaves very little soil coverage. Consequently, organic matter incorporation is very low, so soil structure tends to become unstable and dense. Soybean monoculture cannot counter the structural densification from the cause mentioned and also because the system generates fewer roots and biopores compared to grasses, such as corn, sorghum and wheat. After several years, soybean monoculture soils tend to become denser forming a "floor" or hardened layers which in turn limit the growth of roots and in some cases determine their change in direction (Casas 2006).

In San Luis province, water erosion has been studied in different environments and among the determining factors found are anthropogenic changes in the central-west part of the province with plowing and compacted soil layers. This increases soil density, decreases the number of macropores, decreases infiltration and increases runoff, which magnifies erosion problems. Casagrande *et al.* (2009) mention that small changes in organic matter content alter the apparent maximum density and the susceptibility to compaction. The AMD in virgin soil with 3.7% organic matter reaches 1.1 g/cm^3 while similar soil with 2.1% organic matter exceed 1.4 g/cm^3, which means a significant reduction in water collection, gas exchange, biological activity, and, above all, increased erosion. Soybean monocultures with very small contribution of stubble may be an important factor in soil degradation for these reasons.

Soil salinity is a dynamic spatial, both horizontally and vertically, and temporal attribute and is modified by field management, crop type, changes in vegetation, changes in the level of the water table and erratic rainfall. In low areas or gullies, where the fluctuating water table is near soil surface, saline and/or alkaline soils are present with vegetation adapted to large extreme variations in water levels (drought, flood). In Santa Fe and Córdoba provinces various periods with excessive fluctuations in water availability have occurred, leaving soils -after disappearance of surface water- with the water table close to the surface, so salts are transported by capillarity to the surface horizon. Some of these salts are removed by wind, but also can be carried to greater soil depths by rain or remain in a dynamic state near soil surface. Salinisation is exacerbated by lack of vegetation in worked plots, eliminating wet meadows which utilize water from various soil horizons and from the water table, reducing or eliminating capillary action and subsequent superficial salinisation (L.A. Cerana and J.L. Panigatti, pers. comm.). Pasture elimination, maintenance of little or no vegetative cover, increased temperature as well as compaction by machinery or livestock, enhances capillary action in the soil and increases salinisation (Imbellone *et al.* 2010).

There are also indirect effects from the expansion of the agricultural frontier driven by soybean monoculture upon marginal soils, such as shifting livestock to vulnerable

[11] www.inta.gov.ar

regions (Ortega and Azcuy Ameghino 2009), as the islands of the Parana Delta where pasture is burned to improve grazing conditions. Studies in this area showed that fire significantly affected soil surface layers, characterized by high content of organic matter and in contact with a large quantity of vegetative matter in a low state of decomposition. Changes in soil pH and electrical conductivity also correspond to changes caused by intense fire, with significant impacts, such as potential invasion by exotic species. Under these conditions, soil surface layers are reduced to ashes and exposed to erosion by rain, rising river levels or tidal surges (Kandus *et al.* 2009).

Following application, most of the pesticides reach the soil either after direct application or after foliage wash-off. As a major interface between other environmental compartments, soil plays a preponderant buffering role in the fate of pesticides. Apart from volatilization, the main processes controlling the fate of pesticides in soils are retention by soil particles and degradation, both biotic and abiotic. These coupled bio-physico-chemical processes can lead to a transitory or permanent accumulation of pesticides in soils or, on the contrary, to their elimination from the environment. They determine the pesticide concentration in the soil solution, and have a large influence on pesticide transfer towards ground or surface waters and on their ecotoxicological impacts on soil organisms as well (Chaplain *et al.* 2011).

As previously discussed, the principal herbicide used in soybean cultivation is glyphosate. In general, glyphosate is considered to be strongly absorbed by soil and therefore considered to be almost immobile and unsusceptible to transport. However, experimental findings of mobility and leaching of glyphosate are discussed with respect to current observations and knowledge about the leaching risk of highly adsorbing substances (Vereecken 2005).

There is insufficient information about the effect of agrochemicals on physical, chemical and biological aspects of soil, attributable to the characteristics of chemicals used in soybean production. The high content of fine material in soils favors soybean production for its high exchange capacity, while promoting the partial or total neutralization of most of the molecules and ions applied to crops. The repeated cultivation of soybean leads to a loss of soil organic matter (about 1% of the total or >20% relative), coverage (>60%), biological activity, structural stability (> 40%) and some nutrients such as available P (10-40%). Table 1 summarizes main processes studies and the results obtained in studies conducted in Argentina on impacts of agrochemicals used in soybeans over soil resources.

Soybeans over National Route Nº 12, Entre Ríos.

Rubén D. Quintana

Table 1.-	Main studies related to impacts over soil of agrochemicals used in soybean cultivation conducted in Argentina.	
Process studied	**Main results**	**Bibliographic reference**
Sorptive mechanisms of glyphosate (adsorption and desorption)	Typical Argiudol and Acuic Argiudol showed moderate to high glyphosate adsorption, being isopropilamoniuym salt more adsorbed than the acid glyphosate form. Desorption values between 51% and 69% were determined for both products by in-lab assays.	Maitre *et al.* (2008)
Glyphosate adsorption	Most glyphosate adsorption by iron oxides and clay soils, suggests that the formation of complexes can affect the bioavailability and degradation in soil and water.	Pessagno *et al.* (2008)
Surface runoff and nutrient and glyphosate loss	For tilled soils or soils with low coverage, runoff was six times higher than those recorded for pastures. Runoff is not related to coverage of crop stubble, but primarily with the time soils are used for cropping. Authors concluded that the greater coverage and content of organic matter in top 5 cm of soil reduce nutrient losses and decrease the risk of glyphosate contamination.	Sasal *et al.* (2008)
Runoff	In studies of runoff plots, authors found little loss of N and low levels of glyphosate and AMPA in the runoff water, being less than 0.03% of the amount applied to crops. It was suggested that the peaks of high concentration of glyphosate and AMPA after major rainfall indicate the necessity of analyzing issues related to the timing and conditions of herbicide use.	Sasal *et al.* (2010)
Glyphosate transport in soil profile	In well structured clay soils glyphosate was leached in concentrations above the upper limit of pesticides allowed by the European Union for drinking water. Average losses were 39 g/ha of glyphosate for an application of 8 l/ha, suggesting a potential risk of groundwater contamination.	Costa *et al.* (2010)

On the extensive plains of the Argentine pampas and sectors of the Chaco, the original predominant material soil material is loess. This material, transported by wind, varies in composition from heavy to finer material along a southwest to northeast gradient. The soils of eastern Argentina have more clay and exchange capacity to adsorb ions and complex molecules. From south to north there is a gradient of increasing temperature and soils towards the south have higher content of organic matter, meaning that moving northward soils are more susceptible to degradation due to poor management. In general, the southeast soils have a greater capacity to immobilize chemicals (molecules, metabolites and adjuvants) with decreasing capacities towards the west and northwest. A similar pattern is evident in the loss of organic matter, structural stability and irreversible degradation such as wind erosion.

Water quality and availability

In intensively cultivated regions, wetlands are severely affected by the input of agrochemicals such as pesticides and nutrients, which often enter wetlands binded to soil particles eroded from agricultural land. Runoff is one of the major sources of non-point pesticide contamination of streams (Jergentz *et al.* 2005).

In the principal region of soybean production, farmers use minimal tillage practices to prevent soil loss since the Rolling Pampa is characterized by severe soil damage due to water erosion. During the main period for pesticide application, from November to March, short and heavy rainfalls are very common in the region and cause intensive surface runoff. Together with suspended soil, pesticides are transported to non-target sites such as aquatic ecosystems (Jergentz *et al.* 2005).

In 2009, a group of researchers from the CONICET conducted an exhaustive review on the impacts of glyphosate, its metabolite (AMPA) and the surfactant (POEA) over the environment, human health and ecosystems (CONICET 2009). Regarding the fate of glyphosate and its metabolites in surface water, the report concluded that glyphosate and its salts are highly soluble in water, they bind strongly and rapidly to sediments and particulates, especially in shallow and calm water or those carrying large loads of particulate matter, which removes glyphosate from the water column.

However, in streams close to soybean production areas located at the Pergamino-Arrecifes system (north of Buenos Aires), Peruzzo *et al.* (2008) found glyphosate in surface waters after nearby application as a consequence of drift and through runoff, particularly after a raining event. Thus, depending on the suspended solids and microbial activity, glyphosate can be carried several miles downstream. With proper application, leaching into groundwater or runoff into surface waters is not expected.

The two main pathways for chemicals dissipation in water are microbial degradation and binding to sediments. Glyphosate does not degrade easily in sterile water, but in the presence of microflora (bacteria and fungi) it decomposes to AMPA and eventually to carbon dioxide. Other metabolic pathways have been reported, including subsequent degradation of AMPA to inorganic phosphate and methylamine and then to formaldehyde, and by the pathway of sarcosine to glycine. None of these products are considered to be herbicides and are not expected to be highly toxic to aquatic organisms at concentrations that would arise from the typical use of glyphosate. Photodegradation also occurs under field conditions with sufficient penetration of ultraviolet light (CONICET 2009).

Two Canadian studies cited by CONICET report found that the persistence of glyphosate in water can last between 12 and 60 days after direct application. In the United States, glyphosate residues were found in lake sediments one year after direct application. It has been found that AMPA is more persistent than glyphosate and can persist between 199 and 959 days.

As it was mentioned before the Endosulfan was prohibited in Argentina in 2011, but it has been the second most commonly used insecticide on soybean crop. It is a water-insoluble compound that can be decomposed by photolysis, hydrolysis and biodegradation. In water it has a half life of 35 to 150 days and has been detected in deep groundwater in concentrations ranging from 0.008 to 0.053 ppm up to 20 days after application (Romeo and Quijano 2000).

Table 2.- Main studies related to impacts over water of agrochemicals used in soybean cultivation conducted in Argentina.

Process studied	Main results	Bibliographic reference
Detection of glyphosate in water bodies of the Pergamino- Arrecifes system	Glyphosate concentrations ranged from 0.10 to 0.70 mg/l in water and sediments in streams located near soybean fields, with significant increases in concentration following precipitation events. Sediment samples showed an increase in glyphosate concentration near cultivated areas following applications.	Peruzzo *et al.* (2008)
Glyphosate losses determination by drainage and runoff in soil samples from Pergamino (Buenos Aires province) and Paraná (Entre Ríos province)	Glyphosate applied before sowing was detected in drainage water and the peaks of glyphosate concentrations in drainage and runoff water were registered after important rain events (~10 µg L^{-1}). However, the amount of glyphosate lost throughout the study period was lower than 0.03 and 0.6% of the amounts applied, respectively.	Sasal *et al.* (2010)
Levels of cypermethrin in streams of the Pergamino- Arrecifes system	It was found that pesticides enter the stream. Cypermethrin concentrations peaked in relation to spraying and rainfall events, quickly decreasing to undetectable levels in less than a week during inter-application periods. The lack of effects was in correspondence with the buffering capacity of natural waters, reducing cypermethrin toxicity by up to one order of magnitude. Protective capacity was mainly associated with the organic matter content.	Carriquiriborde *et al.* (2007)
Levels of cypermethrin in a river of the Pergamino- Arrecifes system	Cypermethrin was detected in water and sediments. Spraying events and rainfall after spraying were associated with the presence of pesticides in all samples.	Marino and Ronco (2005)
Levels of endosulfan, cypermethrin and chlorpyriphos in streams tributaries of the Pergamino- Arrecifes system	These insecticides were detected in sediments, as suspended particles in water.	Jergentz *et al.* (2005)

Another aspect from soybean production that needs to be addressed is the risk of wetland eutrophication caused by inorganic fertilizers. A mass balance of nitrogen for soybean demonstrates that increased nitrogen inputs from biological fixation do not compensate for losses due to seed export, such that most areas under soybean cultivation are currently experiencing a substantive net loss of nitrogen. In addition, other crops that are currently being fertilized still show a net loss of nitrogen also due to the effect of primary exports from these agro-ecosystems (Austin *et al.* 2006). Given this, it would be expected that water bodies within areas of soybean production are at risk of nutrient contamination and eutrophication. However, studies of eutrophication due to soybean production are scarce.

Vera *et al.* (2010) investigated the effects of Roundup Ready ® (glyphosate formulation) on the periphyton colonization of experimentally mesocosms. 8mg/l were of active ingredient added; glyphosate half-life estimation was of 4.2 days. Total phosphorus significantly increased due to Roundup degradation, favoring eutrophication process. Due to mortality of algae, mainly diatoms, proliferation of cyanobacteria was favored. Authors concluded that glyphosate produced a long term shift in the typology of mesocosms, “clear” turning to “turbid”, which is consistent with the regional trend in shallow lakes in the Pampa Plain of Argentina. Favoring cyanobacteria development, along with cyanotoxins, may lead to other indirect problems such as bad odor, native wildlife death, etc.

One of glyphosate application techniques includes aerial pulverizations. Air contamination by spraying equipments, whether aerial or terrestrial, may transport chemicals to towns or cities. Moreover, wetlands and native vegetation patches immersed in an agricultural matrix are highly vulnerable to sprayings. Actions can minimize contamination risk, such as considering climate factors or legislation referred to security areas banned for spraying, in case this information exists. Even considering these restrictions, once the atmosphere incorporates the agrotoxics, they can be transported far away from the application point.

The effects on wetlands water quality from agrochemicals used in soybean production in Argentina are poorly studied. One of the main reasons is lack of funding for field studies and scarcity of tools and techniques needed to detect chemicals in water. However, Table 2 highlights key research findings for areas with intensive soybean cultivation.

Fauna

There are different groups of organisms designated as “sentinels” for their role in warning of the presence of toxins in the environment, either by developing various detoxification enzymes or by changes in behavior. In Argentina there is a body of evidence at different levels of organization related to biological indicators regarding the effect of agrochemicals on mainly aquatic organisms. Table 3 summarizes some of the effects observed in these animals. It is noteworthy that the reproductive period of many organisms which breed in the spring and summer overlaps with the period of herbicide application. Furthermore, in many cases this can be longer, such as anurans where larval development may extend for long periods.

Rubén D. Quintana

Greater Rhea, a classic species from the Pampean grassland displaced by agriculture.

Capybara in northeast Argentina wetlands.

Rubén D. Quintana

Rubén D. Quintana

Herons and storks.

Table 3.- Main conclusions of local authors on the effects of agrochemicals over sentinel organisms.

Group of organisms	Agrochemical studied	Effects	Bibliographic reference
Amphibians	cypermethrin	Alters gregarious behavior patterns of larval amphibians that facilitate feeding and increase depredation of intoxicated larvae.	Lajmanovich and Peltzer (2004)
Amphibians	cypermethrin	Apoptosis of amphibian nerve cells.	Izaguirre *et al.* (2000)
Fish	cypermethrin	No effect of mortality or alterations on behavior of resident fish species. No changes in population parameters (size structure, abundance, survival, etc.).	Carriquiriborde *et al.* (2007)
Fish	cypermethrin	Survival of fish (*Odontesthes bonariensis*) decreased at higher temperatures and cypermethrin concentrations, and growth was significantly increased by cypermethrin exposure. Cypermethrin did not cause changes in sex ratios.	Carriquiriborde *et al.* (2009)
Crustaceans	cypermethrin, endosulfan, chlorpyriphos	With peak insecticide contamination of 64 mg/kg Chl, 100% mortality was observed in *Hyalella curvispina* and *Macrobrachium borelli*	Jergentz *et al.* (2004)
Fish	endosulfan	Reduced mobility	Ballesteros *et al.* (2009)
Amphibians	glyphosate cypermethrin endosulfan chlorpyriphos	Increased activity of enzymes related to amphibian detoxification. Differences were found in body length and weight	Brodeur *et al.* (2011)

Flora

Since riparian and aquatic communities are essential for maintaining wetlands habitat quality in agro-ecosystems, many studies have investigated the effects of pesticides on these habitats. Martin *et al.* (2003) studied the riparian vegetation within a section of a stream located between two soybean plots in the pampas, finding that green biomass, species richness, cover and abundance of species vary in relation to herbicide applications in a single harvest cycle. However, in a laboratory study, the same authors observed significant negative effects on total chlorophyll content. Laboratory tests found adverse effects on *Lemnaceae* at 1.3 mg/l and in *Hidrocaritaceae* to 20.1 mg/l of formulated herbicide (glyphosate and facilitators). Martin and Ronco (2006) found higher toxicity to seeds of *Lactuca sativa* by formulated herbicide (glyphosate and facilitators). The increased toxicity may be due to facilitation of herbicide entrance into tissues provided by the other ingredients; however, toxicity tests comparing the effects of glyphosate sprayed and in solution on *Lemma minor* (floating macrophyte) found that plant growth was relatively insensitive to glyphosate dissolved in the culture medium and instead the plants died when applied as an aerosol (Lockhart *et al.* 1989).

Social development and food security

More than 150,000 small and medium farmers have disappeared during the past 20 years unable to adapt to the macroeconomic climate related to soybean monoculture and the associated high taxes, high input costs and dependence on international markets, which are outside the control of some production sectors (Martínez 2010 and pers. comm. 2012). The number of rural enterprises increased from 471,000 in 1947 to 538,000 in 1969, which brought the passage of legislation to prevent subdivision of land that leads to decreasing property size. Between 2002 and 2008 the number of rural enterprises was reduced by 60,000 (333,000 in 2002 and 273,000 in 2008). These developments should bring out a new discussion and regulations in order to reduce the socio-economic effects on the most vulnerable sectors. About 400,000 people dependent on agriculture, not only for food but to maintain their cultural identity, have migrated to big cities or remain in poverty on their own land. Related to this new system governed by soybean monopoly, it has been referred to as a type of farming without farmers, with short-term profitability and irrational use of resources which overshadows their sustainable use.

From a social perspective, agriculture intensification has led to a reduction in the rural labor force. At present, a *pool de siembra* producing soybeans only employs 1.6 hours per person per hectare per year, which is on average four times less than the labor employed 12 years ago (Bragachini *et al.* 2011). While this may free up human capital for work in other economic sectors, many small and medium farmers have not been successful in finding new working areas. For many, livelihoods have been restricted to living off the rent from their lands, or to work for others. Furthermore, changes in land management have led to a rural exodus from the countryside and small rural towns towards the cities in search of better economic opportunities. These changes in ownership and production are leading to the erosion of rural cultures and the loss of traditional knowledge and livelihoods (Pagliaricci and Angel 2012; http://responde.org.ar/sitio). The spread of soybean farming will also have impacts on food sovereignty, as soybeans are cultivated at the expense of traditional livestock and crop production (Tomei and Upham 2009). These true migrations tended to simplify land use, landscape homogenization, biodiversity loss and, above all, the loss of wages and the migration of local labor force. The labor required for various production systems compared with soybeans are highlighted below (Pagliaricci and Angel 2012):

Table 4.-	Labor Wages compared for different production systems.
Production	**Wages/ha/year**
Soybean	1
Dairy	9
Sweet potatoes	20
Roses	75
Citrus (oranges)	60
Peaches	80
Nursery stock	150-200
Figs	300

On the other hand, the advance of the agricultural frontier driven by soybean may generate indirect impacts which affect livelihoods and food security of local communities which depend on wetlands. A clear example occurred in the Parana Delta region, where, as a result of soybean expansion in the pampas, displaced livestock production and some agriculture were relocated. This process was accompanied by concentration of land holdings, wetland deterioration and loss of their goods and services, excluding and/or marginalizing many people in the region whose livelihoods depend on wetland resources.

Summary of impacts

Based upon the information analyzed here, following we present a summary of the main negative impacts of soybean production in Argentina (Table 5).

Wetlands distribution and abundance

The expansion of soybean cultivation has resulted in moderate to high impacts on wetlands for some areas of the soybean production region, mainly due to land reclamation for agricultural use. This is evident in the southeast of Córdoba province and around the Albufera Mar Chiquita in the province of Buenos Aires, with up to 40% reduction in the area of wetlands. In the case of the Bañados de Saladillo reclamation resulted in system degradation and connectivity loss. Biodiversity loss in wetlands has been reported in southern Córdoba and it is possible that the same process is happening in other sectors of the soybean production region. In other cases, it has been documented that wetlands loss has led to direct loss of ecosystem services of local and regional importance. In the case of the Parana Delta, farming intensification as a direct consequence of the expansion of soybean, affected traditional farming practices, resulting in the large fires in 2008, which burned 207,000 ha. In this case, although it has not been quantified, it can be assumed that the amount of GHG emitted into the atmosphere is not negligible.

Soil health

In areas where soybean cultivation predominates, soil properties, natural vegetation and water levels of wetlands are altered, with particular impact on soil erosion and associated deposition in low areas, streams or other runoff pathways. The loss of ground cover due to reduced crop stubble, soil compaction, accelerated extraction of certain nutrients and the expansion of row crop agriculture to areas of low suitability, results in biodiversity loss and changes in water balance. Several of these factors can be avoided, remedied or minimized by the application of available technologies, so major concern and actions must be focused on prevention and control of soil erosion by water and wind, as they are irreversible but avoidable losses.

Water quality and availability

Impact of soybean cultivation on wetland water quality and availability is indirect and low, primarily because the agrochemicals commonly used have low persistence in water and/or are neutralized by sediments or suspended particles. Also, if soybean production is undertaken with responsible practices, the potential effects are minimal. However, due to the characteristics of the large-scale expansion and adoption of soybean production in Argentina, which increases the potential for the erosion of soil resources, there is an increased likelihood for wetland contamination. On the other hand, the little research addressing eutrophication of wetlands show a significant negative impact and is a topic which needs to be taken into account in future studies. As discussed, expansion and intensification of soybean production is likely to continue, and given the nation's political priorities and the ineffective enforcement of environmental regulations, future negative effects of soybean cultivation on water quality and availability will likely increase.

Flora and fauna

According to the evidence presented here, there are direct and indirect effects on flora and fauna associated with aquatic environments of close proximity to areas of soybean production. These effects are mainly produced by agrochemicals in varying concentrations, which affect organisms according to taxa and stage of development. Reduced populations of many aquatic species, as well as physiological and behavioral changes, affect the trophic food chain, causing loss of interactions between organisms and disrupting biological processes which are vital to ecosystem functioning and population dynamics (both plant-plant, plant-microorganisms, plant-animal, animal-animal, animal-ecosystem, ecosystem-microorganisms, etc.), ultimately affecting potential goods and services for agricultural production and human welfare.

Social development and food security

The modernization of agriculture worldwide has resulted in the reduction of rural population. In Argentina this process has been accelerated via increasing area in row crops, particularly soybeans with high level of mechanization and low labor requirements. The problem of such displacement of rural population is enhanced by the deficient preparation and /or training of personnel for other tasks, lack of alternative job offers, the fact that inputs are usually purchased away from places of use, the absence of infrastructure to absorb the unemployed and the overall inadequate planning to minimize the impacts of this process. Furthermore, the designation of a high percentage of soybeans for biofuel production in the near future will entail an increased competition with other uses, markets and prices, subsequently resulting in price increases and social and food availability problems.

Table 5.-	Summary of the main impacts of soybean production in Argentina and references to the studies analyzed.	
Topic	**Impact**	**Information source**
Wetlands distribution and abundance	Loss, disconnection, and degradation of wetlands	Quirós *et al.* (2005), Blanco and Méndez (2010), Brandolin *et al.* (2012), Booman *et al.* (2012), F. Salvucci pers. comm.
	Biodiversity loss	Quirós *et al.* (2005), Brandolin *et al.* (2012).
	Loss of ecosystem services	Blanco and Méndez (2010), Brandolin *et al.* (2012), F. Salvucci pers. comm.
	Greenhouse gas emissions resulting from wetland loss and degradation	Kandus *et al.* (2009)
Soil health	Nutrient loss	Vázquez (2005); Cruzate and Casas (2012)
	Salinization / alkalinisation	L.A. Cerana and J.L. Panigatti, pers. comm.
	Contamination	Costa *el at.* (2010)
	Acidification	Vázquez (2005).
	Erosion	Culasso and De Carli (2001); Casas (2006)
	Compaction	Casas (2006); Casagrande *et al.* (2009); http://inta.gob.ar.suelos
	Increased runoff	Sasal *et al.* (2008)
Water quality and availability	Water contamination	Jergentz *et al.* (2005), Marino and Ronco (2005), Peruzzo *et al.* (2008), CONICET (2009), Sasal *et al.* (2010)
	Eutrophication	Vera *et al.* (2010)
Flora and Fauna	Decreased population of aquatic organisms	Jergentz *et al.* (2004), Carriquiriborde *et al.* (2009)
	Physiological/behavioral changes in aquatic organisms	Izaguire *et al.* (2000); Lajmanovich and Peltzer (2004); Ballesteros *et al.* (2009); Brodeur *et al.* (2011)
	Algal toxicity from agrochemicals	Martin *et al.* (2003); Martin and Ronco (2006)
	Changes in the structure of riparian plant communities	Martin *et al.* (2003)
Social development and food security	Concentration of land ownership and loss of small producers	Martínez (2010) and pers. comm. (2012)
	Loss of traditional livelihoods	Pagliaricci and Angel (2012)
	Job loss	Bragachini *et al.* (2011)
	Loss of rural culture	http://responde.org.ar/sitio

CHAPTER 5

Conclusions and recommendations

South America is the region with the most accelerated growth in soybean production worldwide, with a 30 times increase in cultivated area during the last 40 years (Catacora-Vargas *et al.* 2012). Particularly in Argentina, the introduction of glyphosate-resistant soybean in 1996 and the no-till technology, made soybean cultivation increased at an unprecedented rate. At present, soybean occupies over 60% of the cultivated area and is the main crop used for biodiesel production, making Argentina the fourth largest producer and the first exporter of biodiesel.

Biodiesel exportation from Argentina has grown in a rapid and continued way since 2007, reaching 1.69 million tons by 2011 (Muñoz and Hilbert 2012). According to expert opinion (A. Mascotena pers. comm.), currently around six to eight million tons of soybeans are used for biodiesel production, which constitutes about 14% of total production.

Two well defined areas for soybean production are recognized in Argentina based upon a combination of climate, soil, and potential yield. In the pampas (primary region), soybean production has been intensively developed since the introduction of the Roundup Ready® variety, while the secondary region, particularly northern Argentina, constitutes an area of steady expansion, associated with the development of new drought resistant soybean varieties. This expansion has been undertaken with incomplete knowledge and without land use planning, which has led to environmental degradation and to a process known as *pampeanización* because it entails deforestation of the Chaco forest and its conversion to soybean agriculture fields (Morello *et al.* 2007). Furthermore, soybean production on leased lands is done with the least possible cost, maximizing the economic benefit, with no medium-term considerations, a situation which results in soil and environment deterioration.

Soybean cultivation expansion has been accompanied by a significant increase in pesticides use, especially herbicides and particularly glyphosate (Catacora-Vargas *et al.* 2012). No-till sowing and the use of glyphosate had in turn resulted in the emergence of herbicide-resistant weeds, thus increasing the use of other, more toxic herbicides such as 2,4-D and Paraquat (Catacora-Vargas *et al.* 2012).

Despite the availability of technology which makes possible obtaining higher yields and better quality with minimal environmental effects, short-term planning and economic interests lead to a crop management with low priority to natural resources, including wetland conservation. Soybean cultivation practices and/or expansion over environmentally sensitive and fragile areas, are the most important and predominant concern under the current production model.


RTRS

Soybean pods.

Considering wetlands, two different scenarios can be distinguished regarding soybean production: wetlands landscapes or landscapes with wetlands. In the first case, soybean is not considered as a productive alternative, so wetlands conservation should be maximized along with promoting production systems appropriate for these ecosystems (this is the case of the Parana Delta or the Esteros del Iberá). In the second case, soybean cultivation needs to be undertaken with appropriate care in order to preserve the goods and services provided by wetlands to society, especially considering those allowing agricultural production. However, in most cases the major role of these ecosystems is not yet recognized, resulting in serious degradation and environmental impacts.

According to this review, soybean production and expansion is producing several environmental and social impacts in Argentina, such as wetland degradation or even complete replacement, with the associated biodiversity loss, water pollution and the irreversible loss of rural culture and traditional knowledge.

Environmental impacts of soybean expansion over wetlands can be grouped into two primary categories:

1) Those associated with degradation and loss of wetlands (loss of biodiversity and of ecosystem services, GHG admissions, etc.) and

2) Those associated with agrochemicals (contamination of water and soils, eutrophication, behavioral and physiological changes in fauna, mortality of aquatic biota, etc.).

A critical aspect that needs to be taken into account is the close relationship among the maintenance of the hydrological regime, the structural components of wetlands (biodiversity at all scales) and ecosystem functions. This is a concept that is not considered when planning infrastructure in wetlands such as channeling. Modifying wetlands without recognizing this key aspect has direct effect on the ecological function of wetlands as well as on adjoining systems. Moreover, as economic valuation of ecosystem services is still underdeveloped, in the short-term their management is conditional upon greater apparent benefits perceived from a rapid financial return. These constraints threaten the ecological integrity of wetlands and thereby increase the risk of losing the ecosystem services they provide not only at the ecosystem level, but also and most importantly, at social and economic levels (Kandus *et al.* 2011).

Faced with the advance of soybean along with its associated impacts, it is necessary to identify the mechanisms and tools to promote wetlands conservation and maintenance of water quality.

Although Argentina has various environmental laws for preserving natural resources, there is considerable lack of enforcement and control. While there is a National Law on “Minimum Standards of Environmental Protection of Native Forests”, a similar Law on “Minimum Standards for the conservation of wetland ecosystems” is still missing.

Regarding the implementation of existing regulations, there is a general tendency in both the legal and judicial systems to minimize penalties imposed for environmental crimes, thus insufficient to deter offenders. Furthermore, lack of continuity in government planning as well as the unclear taxing and export permits, make the planning of sustainable production very difficult.

On the other hand, there is a clear deficit of information and awareness among producers and authorities concerning the importance of wetlands and their role as suppliers of goods and services for society and especially for agricultural production.

General knowledge about natural resources and particularly on the available technology to manage natural areas and crops are essential for sustainable land use planning, curbing ecosystem degradation, especially wetland, while obtaining higher crop yields and the long-desired production sustainability. Despite the importance of this knowledge base, without defined policy and the ability to plan in the medium and long-term, the degradation of ecosystems, and particularly wetlands, will continue.

In order to achieve an environmentally sustainable production, it is clear the need of effective policies with adequate standards of sustainability and their enforcement thereof, as well as the adoption of best agricultural practices by producers, based on a clear awareness of the importance of preserving a healthy environment.

Certification schemes for sustainability and wetlands

Driven by the increase demand for biodiesel worldwide, several sustainability certification schemes that meet the requirements of the European Renewable Energy Directive had been developed, three of which would be appropriate for biofuels certification in Argentina and had been adopted by local market (Muñoz and Hilbert 2012): 2BSvs (Biomass and Biofuel Voluntary Sustainability Scheme), ISCC (International Sustainability and Carbon Certification) and RTRS (Round Table for Responsible Soy).

Regarding wetlands, RTRS standard considers:

- Natural wetlands are not drained and native vegetation is maintained
- Good agricultural practices are implemented to minimize diffuse and localized impacts on surface and ground water quality from chemical residues, fertilizers, erosion or other sources and to promote aquifer recharge
- There is no aerial application of pesticides in WHO Class Ia, Ib and II within 500 m of populated areas or water bodies

Although this consideration of wetlands in the RTRS certification is auspicious, it has not yet been analyzed how this ecosystems would be represented in maps of Areas of High Conservation Value (areas banned for soybean cultivation) neither if these maps will be efficient enough in achieving conservation and sustainable use of these ecosystems. Moreover, it still needs to be determined the results of the implementation of the RTRS Standard in the field as well as its monitoring in order to analyze it success for wetland conservation.

Recommendations

According to the results of this work, we suggest the following recommendations towards environmental sustainability of soybean cultivation:

- Regionally, environmental land use planning is a key tool to restrict the expansion of soybean cultivation, limiting entrance into areas of high value for biodiversity conservation, such as wetlands macro-systems, forests and native grasslands.

- Locally, promoting measures to prohibit expansion of soybean cultivation into the margins of rivers, streams, lakes and ponds and to promote vegetation buffer zones around water bodies which prevent contamination by agrochemicals from drift and runoff, while creating refuge for biodiversity.

- To develop and promote guidelines of best agricultural practices among producers, incorporating the environmental component, including wetlands and biodiversity conservation and sustainable management of water resources.

- To promote environmental monitoring, integrated pest management, and the responsible use of agrochemicals in soybean cultivation

- To identify specific indicators for monitoring socio-environmental impacts of the soybean expansion on wetlands, contributing to the development of the "Soybean Observatory", according to the workshop "ONGs sudamericanas enfrentando los desafíos de la expansión de soja" in Brasilia in march 2012 (Instituto Centro de Vida *et al.* 2012).

- Review agrochemical use in soybean production and its impacts on wetlands and biodiversity, particularly glyphosate, 2,4-D, Paraquat, Endosulfan, cypermethrin, chlorpyrifos and carbofuran. To support and encourage research related to water contamination and to establish management guidelines for mitigation of the effects from soybean production.

- There is a real environmental degradation risk, particularly in wetlands, related to glyphosate use and, given the fundamental role played by this herbicide in the current soy production system, it is unrealistic to foresee a decline in its use. However, it is possible to implement rational management of this product by taking the necessary precautions to prevent the generation of resistant weeds, avoiding unnecessary applications, and higher doses than those recommended by manufacturers.

- It is important to generate alternative technologies which reduce the use of glyphosate over the medium-term while avoiding adverse effects on the environment. Moreover, production systems less dependent upon a single herbicide will be less vulnerable to market driven price fluctuations.

- To encourage and strengthen interactions among professionals in scientific and technological disciplines related to environmental research and sustainable production programs, along with extension agents responsible for producers outreach and decision makers concerning responsible soy production.

- Educate producers and other actors in the soybean production chain on the importance of wetlands and their major role as suppliers of goods and services for society, and particularly in agricultural production.

CHAPTER 6

Bibliography and consultations

ADIMRA 2012. Resumen de noticias del sector energético argentino. Noviembre y Diciembre 2011 + Enero 2012 [en línea]. www.adimra.org.ar

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystem and Environment 74: 19-31.

Altieri, M.A. and W.A. Pengue 2006. La soja transgénica en América Latina. Biodiversidad 47:14-19.

Ansink, E., L. Hein and K. Per Hasund. 2008. To Value Functions or Services? An Analysis of Ecosystem Valuation Approaches. Environmental Values 17:489-503.

Aragón, J. 2002. Insectos perjudiciales de la soja y su manejo integrado en la Región Pampeana Central [online]. http://www.inta.gov.ar

Austin, A., G. Piñeiro and M. Gonzalez Polo. 2006. More is less: agricultural impacts on the N cycle in Argentina. Biogeochemistry 79: 45-70.

Ballesteros, M.L., P.E. Durando, M.L. Nores, M.P. Díaz, M.A. Bistoni and D.A. Wunderlin. 2009. Endosulfan induces changes in spontaneous swimming activity and acetylcholinesterase activity of *Jenynsia multidentata* (Anablepidae, Cyprinodontiformes). Environmental Pollution 157: 1573-1580.

Battaglin, W.A, D.W. Kolpin, E.A. Scribner, K.M. Kuivila and M.W. Sandstrom. 2005. Glyphosate, other herbicides, and transformation products in Midwestern streams. Journal of the American Water Resources Association 41: 323-332.

Bertonati, C. and J. Corcuera. 2000. Situación Ambiental Argentina 2000. Fundación Vida Silvestre Argentina. Buenos Aires, Argentina. 436 pp.

Blanco, D.E. and F.M. Méndez (eds.). 2010. Endicamientos y terraplenes en el Delta del Paraná: situación, efectos ambientales y marco jurídico. Fundación Humedales / Wetlands International. Buenos Aires, Argentina.

Booman, G.C., M. Callandroni, P. Laterra, F. Cabria, O. Iribarne y P. Vázquez. Areal changes of lentic water bodies within an agricultural basin of the Argentinean pampas. Disentangling land management from climatic causes. Environmental Management 50:1058-1067.

Bradberry, S.M., A.T. Proudfoot and J.A. Vale. 2004. Glyphosate Poisoning. Toxicological Reviews 23:159-167.

Bragachini, M. 2010. Rol de la agricultura de precisión en el proceso productivo y su futuro hacia la competitividad global. 9º Curso de Agricultura de Precisión y 4ª Expo de Máquinas Precisas, Manfredi, Córdoba, Argentina [online]. http://agriculturadeprecision.org

Bragachini, M., C. Casini. A. Saavedra, J. Méndez, R. de Carli, E. Behr, L. Errasquin, F. Ustarroz and M. Bragachini. 2011. Evolución del sistema productivo agropecuario en Argentina. Proyecto Agregado de Valor en Origen – PRECOP II. Ediciones INTA.

Brandolin, P.G., M.A. Ávalos and C. De Angelo. 2012. The impact of flood control on the loss of wetlands in Argentina. Aquatic Conservation: Marine and Freshwater Ecosystems [online]. http://onlinelibrary.wiley.com

Brodeur, J.C., R.P. Suarez, G.S. Natale, A.E. Ronco and M.E. Zacagnini. 2011. Reduced body condition and enzymatic alterations in frogs inhabiting intensive crop production areas. Ecotoxicology and Environmental Safety 74: 1370-1380.

Bucher, E.H. and J.M. Chani. 1999. Chaco. In Canevari, P., D.E. Blanco, E.H. Bucher, G. Castro and I. Davison (eds.): Los Humedales de la Argentina: Clasificación, Situación Actual, Conservación y Legislación. Wetlands International Publ. 46 (2nd. Edition), Buenos Aires. 208 pp. + ii.

CADER. 2008. Outlook for the Argentine biodiesel industry. Cámara Argentina de Energías Renovables, Buenos Aires. [online]. http://www.argentinarenovables.org

CADER. 2009. Estado de la industria argentina de biodiesel. Reporte segundo cuatrimestre de 2009.

Canevari, P., D.E. Blanco, E.H. Bucher, G. Castro and I. Davison (eds.). 1999. Los Humedales de la Argentina: Clasificación, Situación Actual, Conservación y Legislación. Wetlands International Publ. 46 (2nd. Edition), Buenos Aires. 208 pp. + ii.

Carriquiriborde, P., J. Díaz, H. Mugni, C. Bonetto and A. Ronco. 2007. Impact of cypermethrin on stream fish populations under field-use in biotech-soybean production. Chemosphere 68: 613-621.

Carriquiriborde, P., J. Díaz, G.C. López, A.E. Ronco and G.M. Somoz. 2009. Effects of cypermethrin chronic exposure and water temperature on survival, growth, sex differentiation, and gonadal developmental stages of *Odontesthes bonariensis* (Teleostei) Chemosphere 76: 374-380.

Casagrande, J., A. Quiroga, I. Frasier and J.C. Colazo. 2009. Aspectos de la evaluación y el manejo de suelos afectados por compactación en San Luis. In Quiroga A., J. Casagrande y J. Colazo (eds.): Aspectos de la evaluación y el manejo de los suelos en el este de San Luis. Información Técnica 173, INTA San Luis. 15-21 pp.

Casas, R.R. 2006. Preservar la calidad y salud de los suelos, oportunidad para la Argentina. Academia Nacional de Agronomía y Veterinaria. Annals: Volume LX. Buenos Aires.

Catacora-Vargas, G., P. Galeano, S. Zanon Agapito-Tenfen, D. Aranda, T. Palau and R. Onofre Nodari. 2012. Producción de soya en las Américas: actualización sobre el uso de tierras y pesticidas [online]. http://www.redes.org.uy

Chang, F., M.F. Simcik and P.D. Capel. 2011. Occurrence and fate of the herbicide glyphosate and its degradate aminomethylphosphonic acid in the atmosphere: Environmental Toxicology and Chemistry 30: 548-555.

Chaplain, V., L. Mamy, L. Vieublé-Gonod, C. Mougin, P. Benoit, E. Barriuso and S. Nélieu. 2011. Fate of pesticides in soils: toward an integrated approach of influential factors. In Stoytchev, M. (ed.): Pesticides in the Modern World - Risks and Benefits. InTech [online]. http://www.intechopen.com

CONICET 2009. Evaluación de la información científica vinculada al glifosato en su incidencia sobre la salud humana y el ambiente [online]. http://www.msal.gov.ar

Costa, J.L., V. Aparicio, M. Zelaya, V. Gianelli and F. Bedmar. 2010. Transporte de glifosato en el perfil de un suelo del sudeste bonaerense. In Camino, M. and V. Aparicio (eds.): Aspectos ambientales del uso de glifosato. INTA Editions.

Constanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, G.R. Raskin, P. Sutton and M. van der Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

Cruzate, G. and R. Casas. 2003. Balance de nutrientes. Fertilizar. Year 8. Special Number “Sostenibilidad”: 7-13.

Cruzate, G.A. and R. Casas. 2009. Extracción de nutrientes en la agricultura Argentina. Informaciones Agronómicas del Cono Sur N° 44: 21-26.

Cruzate, G.A. and R. Casas. 2012. Extracción y balance de nutrientes en los suelos agrícolas de la Argentina. Informaciones Agronómicas de Hispanoamérica. IPNI. Informaciones Agronómicas de Hispanoamérica 6:7-14.

Culasso, I. and R. De Carli. 2001. Desarrollo de la siembra directa en Entre Ríos. In Panigatti, J.L., D. Buschiazzo y H. Marelli: Siembra directa. II. INTA Editions.

Doornbosch, R. and R. Steenblik. 2007. Biofuels: Is the cure worse than the disease? Organisation for Economic Co-operation and Development Roundtable on Sustainable Development, Paris [online]. http://media.ft.com

Engler, P., M. Rodríguez, R. Cancio, M. Handloser and L.M. Vera. 2008. Zonas agro económicas homogéneas Entre Ríos, descripción ambiental, socioeconómica y productiva. Estudios socioeconómicos de la sustentabilidad de los sistemas de producción y recursos naturales Nº 6, INTA. Buenos Aires, Argentina. 150 pp.

EPA. 1993. Glyphosate (CASRN 1071-83-6). Integrated Risk Information System [online]. http://www.epa.gov

FAO. 2008. El estado mundial de la agricultura y la alimentación. Biocombustibles: perspectivas, riesgos y oportunidades [online]. www.fao.org

Fargione J., J. Hill, D. Tilman, S. Polasky and P. Hawthorne P. 2008. Land clearing and the biofuel carbon debt. Science 319:1235–38.

Franz, J.E., M.K.Mao and J.A. Sikorski. 1997. Glyphosate: a unique global herbicide. ACS Monograph 189, American Chemical Society, Washington, DC, 653 pp.

Fundación Vida Silvestre Argentina (FVSA) and Fundación para el Desarrollo en Justicia y Paz (FUNDAPAZ). 2007. Zonificación de los Bajos Submeridionales del Norte Santafesino. Una Herramienta para la Planificación del Desarrollo Productivo y la Conservación de la Biodiversidad del Humedal. Buenos Aires. Vida Silvestre Argentina.

García, F.O., I. A. Ciampitti and H. Baigorri (eds.). 2009. Manual de manejo del cultivo de soja. IPNI. Acassuso, Buenos Aires, Argentina. 180 p.

Gasparri, N.I. and H.R. Grau. 2006. Patrones regionales de deforestación en el subtrópico argentino y su contexto ecológico y socioeconómico. In Brown, A.D., U. Martinez Ortiz, M. Acerbi y J. Corcuera (eds.): La Situación Ambiental Argentina. Fundación Vida Silvestre Argentina. Buenos Aires.

Giesy, J.P., S. Dobson and K.R. Solomon. 2000. Ecotoxicological risk assessment for Roundup® herbicide. Reviews of Environmental Contamination and Toxicology 167:35-120.

Gnansounou, E., A. Dauriat, J. Villegas and L. Panichelli. 2009. Life cycle assessment of biofuels: Energy and greenhouse gas balances. Bioresource Technology 100: 4919-4930.

Gómez A.L, A. Alfieri and M. Angelini. 2006. Estudio de Suelos en la Reserva Biósfera Delta del Paraná. INTA Castelar. Buenos Aires, Argentina.

Gómez S.E. and N.I. Toresani. 1999. Pampas. In Canevari, P., D.E. Blanco, E.H. Bucher, G. Castro and I. Davison (eds.): Los Humedales de la Argentina: Clasificación, Situación Actual, Conservación y Legislación. Wetlands International Publ. 46 (2nd. Edition), Buenos Aires. 208 pp. + ii.

Goveto L., C. Saibene, P. Moreyra, N. Villarreal, M.E. Nale, M. Romitti, M. Méndez y M. Campos (comps.). Ramsar Information Sheet on Wetlands of Otamendi Natural Reserve [online]. http://www.ambiente.gov.ar

Grau, R, M. Aide and I. Gasparri. 2005. Globalization and soybean expansion into semiarid ecoystems of Argentina. Ambio 34:265-266.

Imbellone, P.A., J.E. Giménez and J.L. Panigatti. 2010. Suelos de la Región Pampeana. Procesos de formación. INTA Editions. Buenos Aires. 320 pp.

Instituto Centro de Vida, Both Ends y UICN Países Bajos. 2012. Soy Workshop, Final Report. Brasilia March 2012.

IPCS. 1994. Environmental Criteria no. 152. Polybrominated biphenyls. WHO, Geneva.

Izaguirre, M.F., R.C. Lajmanovich, P.M. Peltzer, A. Peralta Soler and V.H. Casco. 2000. Cypermethrin-induced apoptosis in the Telencephalon of *Physalaemus biligonigerus* tadpoles (Anura: Leptodactylidae). Bulletin of *Environmental Contamination and Toxicol*ogy 65: 501-507.

Jergentz, S., P. Pessacq, H. Mugni, C. Bonetto and R. Schulz. 2004. Linking in situ bioassays and population dynamics of macroinvertebrates to assess agricultural contamination in streams of the Argentine pampa. Ecotoxicology and Environmental Safety 59: 133–141.

Jergentz, S., H. Mugni, C. Bonetto and R. Schulz. 2005. Assessment of insecticide contamination in runoff and stream water of small agricultural streams in the main soybean area of Argentina. Chemosphere 61: 817–826.

Jóbbagy, E.G. and C. Santoni. 2006. La (nueva) agricultura y la hidrología en la llanura chaco pampeana: Desafíos para las próximas décadas. XXII Reunión Argentina de Ecología. “Fronteras en Ecología: hechos y perspectivas”. August 22nd to 25th, Córdoba, Argentina.

Joensen, L., S. Semino and H. Paul. 2005. Argentina: A case study on the impact of genetically engineered soya. How producing RR soya is destroying the food security and sovereignty of Argentina. Gaia Foundation, London [online]. http://www.econexus.info

Kandus, P., P. Minotti and A.I. Malvárez. 2008. Distribution of wetlands in Argentina estimated from soil charts. Acta Scientiarum 30 (4): 403-409.

Kandus, P., M. Salvia, D. Ceballos, N. Madanes, V. Cappello, M. García Cortes and M. Morais. 2009. Incendios de 2008 en el Delta Del Río Paraná, Argentina. Análisis ecológico sobre el sector de islas frente a las localidades de Zárate, Baradero y San Pedro. Technical report.

Kandus, P. and P. Minotti. 2010. Distribución de terraplenes y áreas endicadas en la región del Delta del Paraná. In Blanco, D.E. y F.M. Méndez (eds.): Endicamientos y terraplenes en el Delta del Paraná: situación, efectos ambientales y marco jurídico. Fundación Humedales / Wetlands International. Buenos Aires.

Kandus, P., R.D. Quintana, P. Minotti, J. Oddi, C. Baigún, G. González Trilla and D. Ceballos. 2011. Ecosistemas de humedal y una perspectiva hidrogeomórfica como marco para la valoración ecológica de sus bienes y servicios. In Laterra, P., E.G. Jobbágy, J.M. Paruelo (eds.): Valoración de servicios ecosistémicos: conceptos, herramientas y aplicaciones para el ordenamiento territorial. INTA Editions. Buenos Aires. 740 pp.

Koh, L. and J. Ghazoul. 2008. Biofuels, biodiversity, and people: Understanding the conflicts and finding opportunities. Biological Conservation 141: 2450-2460.

Lajmanovich, R.C. and P.M. Peltzer. 2004. Aportes al Conocimiento de los Anfibios Anuros con Distribución en las Provincias de Santa Fe y Entre Ríos (Biología, Diversidad, Ecotoxicología y Conservación). In Temas de la Biodiversidad del Litoral Fluvial Argentino. INSUGEO, Miscelánea, 12: 291-302. Tucumán.

Lamers, P. 2006. Emerging liquid biofuel markets: ¿Adónde va la Argentina? IIEE thesis: Lund, Sweden.

Lockhart, W.L., B.N. Billeck and C.L. Baron. 1989. Bioassays with a floating aquatic plant (*Lemna minor*) for effects of sprayed and dissolved glyphosate. Hydrobiologia 189: 353–359

Maitre, M.I., E. Lorenzatti, A. Lenardón and S. Enrique. 2008. Adsorption and desorption of glyphosate in two argentinian soil. Natura Neotropicalis 39: 20-31

Marino, D. and A. Ronco. 2005. Cypermethrin and chlorpyrifos concentration levels in surface water bodies of the Pampa Ondulada, Argentina. Environmental Contamination and Toxicology 75: 820-826.

Martin, M.L. and A.E. Ronco. 2006. Effects of mixtures of pesticides used in the direct seeding technique on non-target plant seeds. Bulletin of Environmental Contamination and Toxicology 77: 228-236.

Martin, M.L., C. Sobrero, C. Rivas, F. Rimoldi and A. Ronco. 2003. Impacto del uso de pesticidas asociados a la siembra directa sobre especies no-blanco. Flora riparia y acuática. Conferencia Internacional Usos Múltiples del Agua: para la vida y el desarrollo sostenible, Cartagena de Indias.

Martínez, F. 2010. Crónica de la soja en la región pampeana argentina. Para mejorar la producción 45: 141-146.

Massaro, R.A. 2010. Prácticas de manejo de plagas insectiles para revisar. Para mejorar la producción 45. INTA EEA Oliveros.

Maund, S., M. Hamer, M. Lane, E. Farrelly, J. Rapley, U. Goggin and W. Gentle. 2002. Partitioning, bioavailability, and toxicity of the pyrethroid insecticide cypermethrin in sediments. Environ. Toxicol. Chem. 21: 9-15.

Monti, M. 2008. Retenciones móviles en los granos: impactos económicos en el Distrito de Rufino. Dirección de Extensión e Investigación Agropecuaria, Ministerio de la Producción, Santa Fe.

Morello, J., W. Pengue and A.F. Rodriguez. 2007. Un siglo de cambios de diseño del paisaje: el Chaco Argentino. In Mateucci, S. (ed.): Panorama de la ecología de paisajes en Argentina y países sudamericanos. INTA Editions.

Muñoz, L. and J.A. Hilbert. 2012. Biocombustibles: El avance de la certificación de sustentabilidad en la Argentina. Informes Técnicos Bioenergía. Year 1, Nº2. INTA Editions.

Nandula, V.K., K.N. Reddy, S.O. Duke and D.H. Poston. 2005. Glyphosate-resistant weeds: current status and future outlook. Outlooks on Pest Management, August: 183-187.

Ortega, L.E. and E. Azcuy Ameghino. 2009. Expansión de la frontera agropecuaria, restructuración ganadera y sojización en regiones extrapampeanas. XV Jornadas de Epistemología de las Ciencias Económicas. Facultad de Ciencias Económicas. Universidad de Buenos Aires. October 1st and 2nd.

Pagliaricci, L. and A.N. Angel. 2012. Evolución de la actividad frutícola en el partido de San Pedro. In Producción del duraznero en la Región Pampeana, Argentina. INTA EEA San Pedro.

Panichelli, L., A. Dauriat and E. Gnansounou. 2009. Life cycle assessment of soybean-based biodiesel in Argentina for export. Int. J. Life Cycle Assess 14:144–159.

Panigatti, J.L. 1976. Molisoles del norte de la zona pampeana. III. Cambios debidos a diferentes manejos. RIA. Series 3. XII (3): 129-143.

Peiretti, R. 2011. La Siembra Directa y las Instituciones de Productores. Sus roles frente al desafío de aumentar la producción agrícola global en forma sustentable. 20th Aapresid Congress. Rosario, Santa Fe.

Peruzzo, P.J., A.A. Porta and A.E. Ronco. 2008. Levels of glyphosate in surface waters, sediments and soils associated with direct sowing soybean cultivation in north pampasic region of Argentina. Environmental Pollution 156: 60-61.

Pessagno, M.R., R.M. Torres Sánchez and M.A. dos Santos. 2008. Glyphosate behavior at soil and mineral-water interfaces. Environmental Pollution 153: 53–5

Pognante, J., M. Bragachini and C. Casini. 2011. Siembra directa. Ediciones INTA [online]. http://www.inta.gov.ar/

Poledo, M. 2009. Mercado doméstico de biodiesel. In IDIA XXI: 12 [online]. http://www.inta.gov.ar/

Quirós, R., M.B. Boveri, C.A. Petracchi, A.M. Ranella, J.J. Rosso, A. Sosnovsky and H.T. von Bernard. 2005. Los efectos de la agriculturización del humedal pampeano sobre la eutrofización de sus lagunas. Eutrifizaçao na América do Sul: Causas, conseqüências e tecnologías de gestão. Rede ETROSUL, PROSUL, São Carlos, Brasil. Second draft.

Racke, K. D. 1993. Environmental fate of chlorpyrifos. Reviews of Environmental Contamination and Toxicology 131:1-150.

Ramsar. 2008. 10th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands: “Healthy Wetlands, Healthy People”. 28 October - 4 November. Changwon, Republic of Korea [online]. http://www.ramsar.org

Righelato, R. and D.V. Spracklen. 2007. Carbon mitigation by biofuels or by saving and restoring forests? Science 317:902.

Romeo, F. and M.D. Quijano. 2000. Risk Assessment in a third world reality: an endosulfan case history. International Journal of Occupational and Environment Health. Vol. 6, Nº4.

Sasal, M.C., M.G. Wilson and N.A. Garciarena. 2008. Escurrimiento superficial y pérdida de nutrientes y glifosato en secuencias de cultivos. En Agricultura Sustentable. INTA EEA Paraná. Serie Extensión N° 51: 40-48.

Sasal, M., A. Andriulo, M. Wilson and S. Portela. 2010. Pérdidas de glifosato por drenaje y escurrimiento en molisoles bajo siembra directa. Información Tecnológica. Vol. 21(5): 135-142.

Scott, D.A and M. Carbonell. 1986. Inventario de humedales de la Región Neotropical. IWRB. Slimbridge, U.K.

Scheinkerman de Obschatko, E. and F. Begenisic (coord.). 2006. Perspectivas de los biocombustibles en la Argentina y en Brasil. 1a ed. Instituto Interamericano de Cooperación para la Agricultura - IICA: Secretaría de Agricultura Ganadería, Pesca y Alimentación - SAGPyA. Buenos Aires.

Searchinger, T., R. Heimlich, R. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes and T. Yu. 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319: 1238-1240.

Thrupp, L.A. 2000. Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture. International Affairs - INT AFF 76 (2): 283-297.

Tomei, J. and P. Upham. 2009. Argentinean soy based biodiesel: An introduction to production and impacts. Tyndall Working Paper 132, April [online]. http://www.tyndall.ac.uk

USDA. 2010. Northern Argentina Production Potential Continues to Grow. USDA Foreign Agricultural Service Commodity intelligence Report [online]. http://www.pecad.fas.usda.gov

Vázquez, M.E. 2005. Calcio y magnesio, acidez y alcalinidad del suelo. In Echeverria, H.E. and F.O. Garcia (eds.): Fertilidad y Fertilización de Cultivos. INTA Editions. Buenos Aires.

Vera, M.S., L. Lagomarsino, M. Sylvester, G.L. Pérez, P. Rodríguez, H. Mugni, R. Sinistro, M. Ferraro, C. Bonetto, H. Zagarese and H. Pizarro. 2010. New evidences of Roundup (glyphosate formulation) impact on the periphyton community and the water quality of freshwater ecosystems. Ecotoxicology 19: 710-721.

Vereecken, H. 2005. Mobility and leaching of glyphosate: a review. Pest Management Science 61:1139–1151.

Weyland, F., S.L. Poggio and C.M. Ghersa. 2008. Agricultura y Biodiversidad. Ciencia Hoy 106: 27-35.

Zaccagnini, M.E. and N.C. Calamari. 2001. Labranzas conservacionistas, siembra directa y biodiversidad. In Panigatti, J.L., D. Buschiazzo y H. Marelli (eds.): Siembra Directa II. INTA, Buenos Aires.

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Institutions abbreviations list

Aapresid	Asociación Argentina de Productores de Siembra Directa (Argentinean Association of No-till Producers)
CONICET	Consejo Nacional de Investigaciones Científicas y Técnicas (National Commission for Scientific and Technological Research)
CREA	Consorcio Regional de Experimentación Agrícola (Regional Consortium of Agricultural Experimentation)
EPA	US Environmental Protection Agency
EU	European Union
FAO	United Nations Food and Agriculture Organisation
GEF	Global Environment Fund
IICA PROCISUR	Programa Cooperativo para el Desarrollo Tecnológico, Agroalimentario y Agroindustrial del Cono Sur del Instituto Interamericano de Cooperación para la Agricultura (Cooperative Programe for the Technological, Agrifood and Industrial of the Southern Cone of the Interamerican Institute of Agricultural Cooperation)
INPOFOS	Instituto de la Potasa y el Fósforo (Potase and Phosphorus Institute)
INTA	Instituto Nacional de Tecnología Agropecuaria (National Institute of Farming and Agricultural Technology)
INTI	Instituto Nacional de Tecnología Industrial (National Institute of Industrial Technology)
MAGyP	Ministerio de Agricultura, Ganadería y Pesca de la Nación (Agriculture, Ranching and Fishing National Ministry)
MCTIP	Ministerio de Ciencia, Tecnología e Innovación Productiva (Ministry of Science, Technology and Productive Innovation)
POEA	Polyethylenediamine
RTRS	Round Table for Responsible Soy
SAGPyA	Secretaría de Agricultura, Ganadería, Pesca y Alimentos de la Nación (Agriculture, Ranching, Fishing and Food National Secretariat)
SAyDS	Secretaría de Ambiente y Desarrollo Sustentable de la Nación (Environment and Sustainable Development National Secretariat)
SE	Secretaría de Energía (Energy Secretariat)
SENASA	Servicio Nacional de Sanidad y Calidad Agroalimentaria (National Service of Agrifood Health and Quality)
UNIDO	United Nations Industrial Development Organisation
WHO	United NationsWorld Health Organisation
YPF	Yacimientos Petrolíferos Fiscales (State Oilfields)

Other abbreviations

2BSvs	Biomass Biofuels Sustainability voluntary scheme
AMPA	Aminomethylphosphonic acid
GHG	Green-house gases
GIS	Geographic Information System
ISCC	International Sutainability and Carbon Certification
OM	Organic matter
OAT	Environmental land use planning
POEA	Polyethylenediamine

Figuras

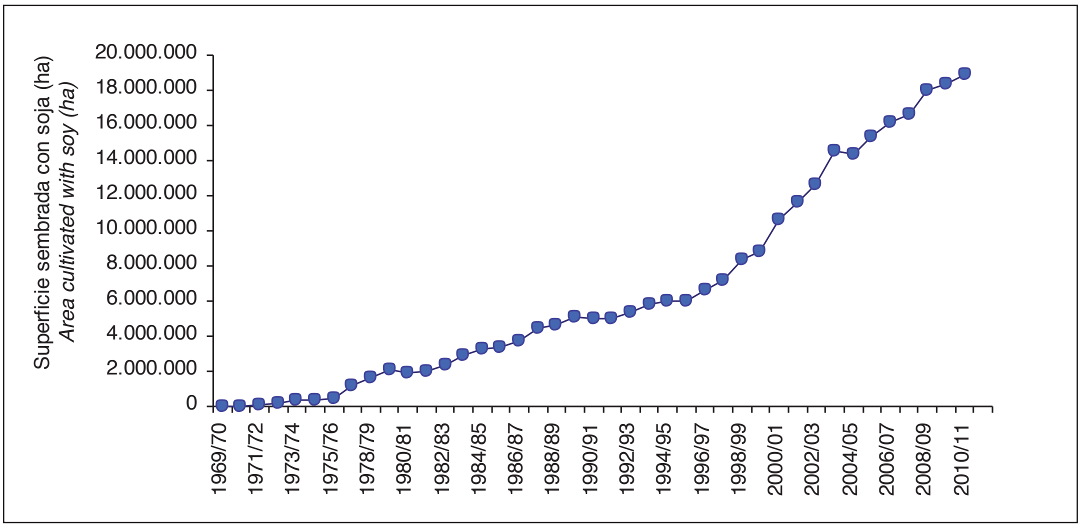

Figura 1.- Evolución del área sembrada con soja en Argentina. *Fuente*: MAGyP / ***Figure 1.-*** *Soybean cultivated area in Argentina Source: MAGyP.*

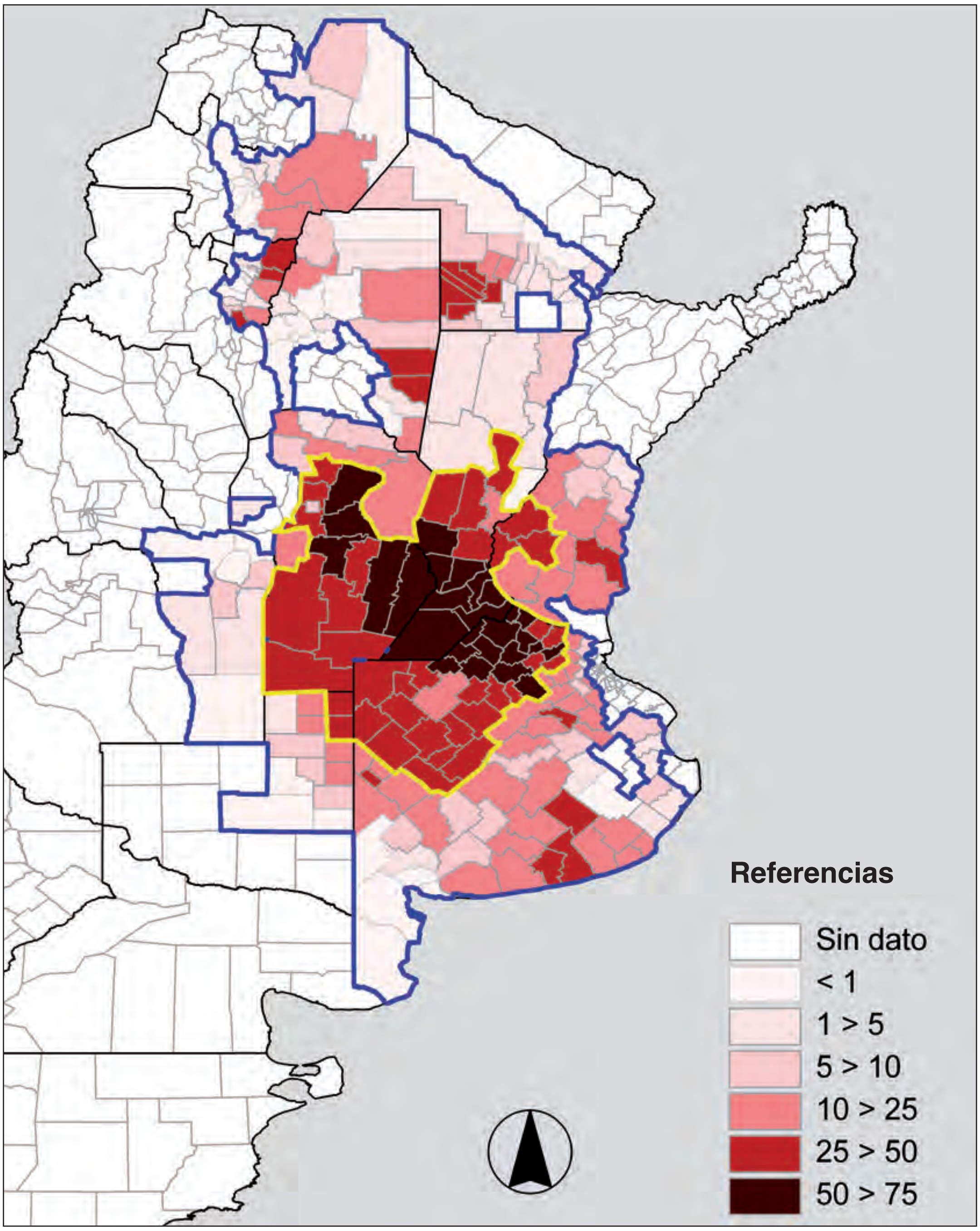

Figura 2.- Distribución del cultivo de soja en Argentina, discriminando el porcentaje de la superficie cultivada por departamento correspondiente a la región primaria (contorno amarillo) y a la secundaria (contorno azul). *Fuente*: MAGyP / ***Figure 2.-*** *Soybean distribution in Argentina, classified by porcentage of area cultivated per department in the primary (yellow outline) and secondary (blue outline) regions. Source: MAGyP.*

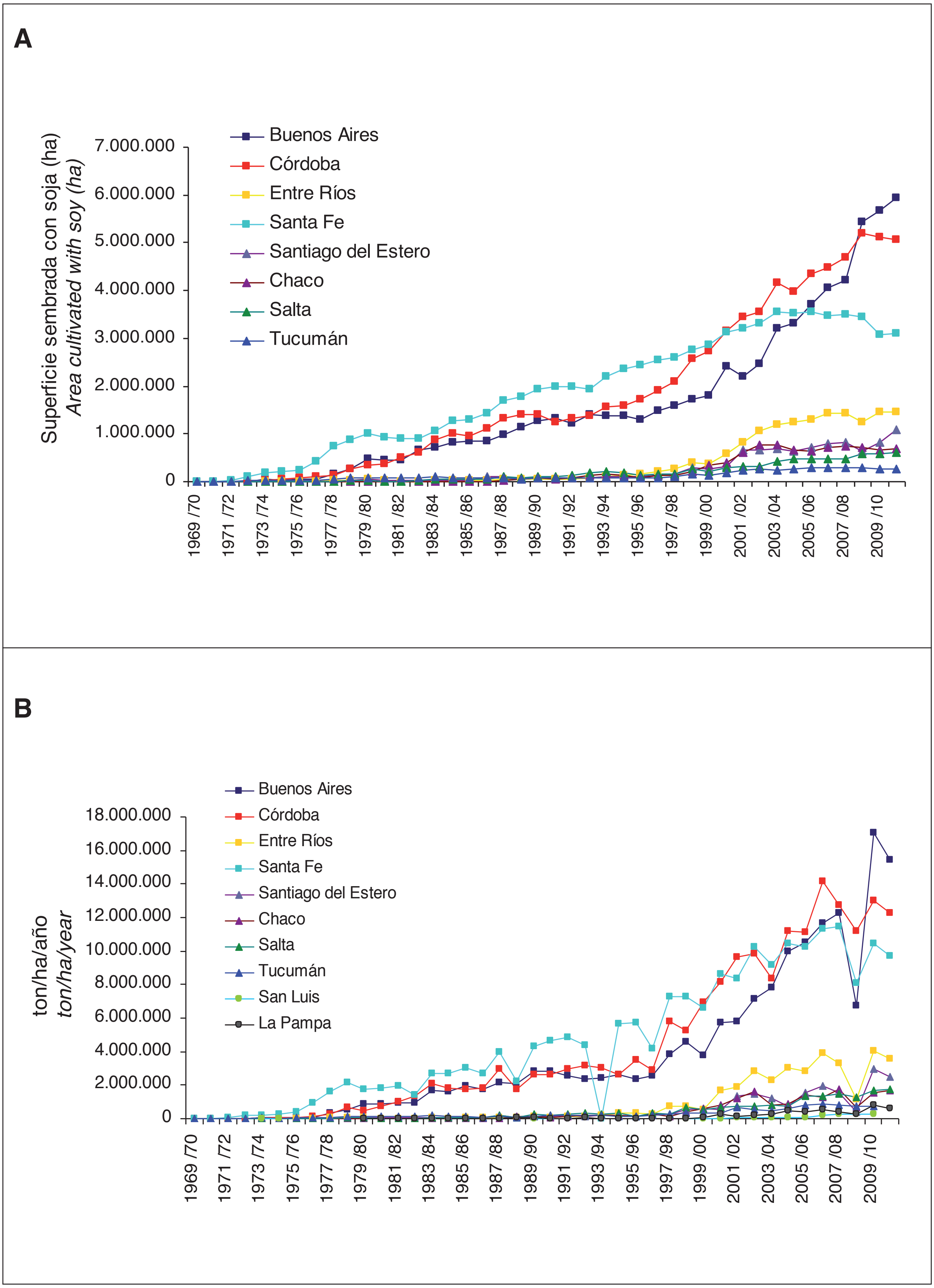

Figura 3.- Evolución del cultivo de soja por provincia para el período 1969-2011: A) superficie sembrada en hectáreas y B) producción de soja (en toneladas/hectárea al año). *Fuente*: MAGyP / ***Figure 3.-*** *Trends on soybean cultivation, sorted by province for the period 1969-2011: A) sown area in hectares and B) soybean production (in tons/hectare per year). Source: MAGyP.*

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Figura 4.- Producción de soja en un establecimiento de Pergamino, provincia de Buenos Aires / ***Figure 4.-*** *Soybeans on a farm in Pergamino, Buenos Aires province.*

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Figura 5.- Cultivo de soja luego de desmonte en el suroeste de Entre Ríos / ***Figure 5.-*** *Soybean cultivation following deforestation in the southwest of Entre Ríos province.*

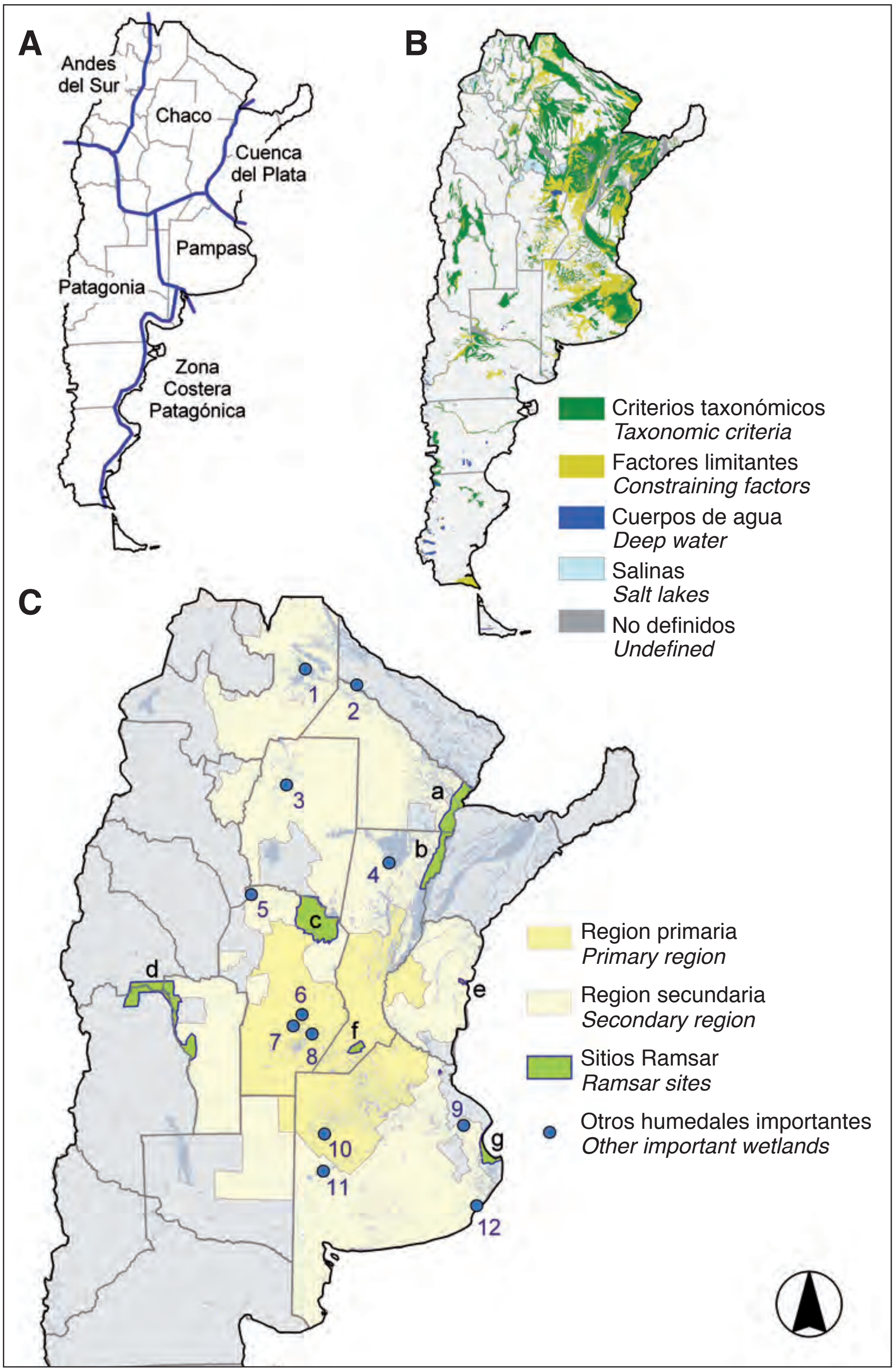

Figura 6.- Humedales de la Argentina: A) Regiones de humedales según Canevari *et al.* (1999), B) mapa de distribución de humedales según Kandus *et al.* (2008)[1] y C) principales humedales localizados en las regiones primaria y secundaria de cultivo de soja, incluyendo sitios Ramsar y otros humedales de importancia. Sitios Ramsar: a) Humedales Chaco, b) Jaaukanigás, c) Bañados del Río Dulce y Laguna de Mar Chiquita, d) Lagunas de Guanacache, Desaguadero y del Bebedero, e) Palmar Yatay, f) Humedal Laguna Melincué y g) Bahía de Samborombón. Otros humedales importantes: 1) Bañados de Quirquincho, 2) Reserva Natural Formosa, 3) Bañados de Figueroa, 4) Bajos Submeridionales, 5) Salinas Grandes, 6) Lagunas de Etruria, 7) Laguna Ludueña, 8) Bañados del Río Saladillo, 9) Sistema de Chascomús, 10) Complejo Lagunar Las Tunas-El Hinojo, 11) Sistema de Lagunas Encadenadas del Oeste y 12) Albufera Mar Chiquita / ***Figure 6.-*** *Wetlands of Argentina: A) wetland regions according to Canevari et al. (1999), B) map of wetlands distribution according to Kandus et al. (2008)[2] and C) main wetland sites within the primary and secondary regions of soybean cultivation, including Ramsar sites and other important wetlands. Ramsar sites: a) Humedales Chaco, b) Jaaukanigás, c) Bañados del Río Dulce y Laguna de Mar Chiquita, d) Lagunas de Guanacache, Desaguadero y del Bebedero, e) Palmar Yatay, f) Humedal Laguna Melincué and g) Bahía de Samborombón. Other important wetlands: 1) Bañados de Quirquincho, 2) Reserva Natural Formosa, 3) Bañados de Figueroa, 4) Bajos Submeridionales, 5) Salinas Grandes, 6) Lagunas de Etruria, 7) Laguna Ludueña, 8) Bañados del Río Saladillo, 9) Sistema de Chascomús, 10) Complejo Lagunar Las Tunas-El Hinojo, 11) Sistema de Lagunas Encadenadas del Oeste and 12) Albufera Mar Chiquita.*

[1] Mapa de Humedales de Argentina elaborado a partir de la carta de suelos a escala 1:250.000 (INTA 1995). **Criterios taxonómicos**: áreas de humedales definidos por el carácter taxonómico de los suelos; **factores limitantes**: áreas de humedales derivados de la acción de condiciones limitantes.

[2] Map of wetlands of Argentina estimated from soil charts at scale 1:250.000 (INTA 1995). **Taxonomic criteria**: wetland areas defined by the taxonomic character of soils; **constraining factors**: wetland areas resulting from the action of constraining conditions.

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Figura 7.- Cultivo de soja y salud del suelo en la provincia de Entre Ríos: A) degradación del suelo por compactación por cosecha de soja en suelo con exceso de humedad y B) erosión en cárcavas, surcos y laminar por cultivos repetidos, principalmente soja / ***Figure 7.-*** *Soybean cultivation and soil health in Entre Ríos province: A) soil degradation by compaction from soybean harvest on soils with excessive moisture and B) erosion in gullies and ruts in repeatedly cultivated field, mainly for soybeans.*

Misión:

Preservar y restaurar los humedales, sus recursos y biodiversidad, para las futuras generaciones.

Mission:

To sustain and restore wetlands, their resources and biodiversity for future generations.

Los biocombustibles surgen como respuesta al acelerado agotamiento de los recursos energéticos fósiles y como un producto cuya combustión reduce la emisión de gases de efecto invernadero respecto a los carburantes fósiles. Sin embargo, con el incremento del empleo de biocombustibles a partir de cultivos agrícolas, se ha originado un debate acerca de los impactos de estos productos sobre el medio ambiente. En la actualidad la soja representa más del 60% de la superficie cultivada de la Argentina, siendo el principal cultivo para la producción de biodiesel y convirtiendo al país en el cuarto productor de biocombustibles y en el primer exportador a nivel mundial. En esta publicación se recopila y analiza la información actual disponible en relación al cultivo de soja en Argentina y a los impactos de su producción sobre los ecosistemas de humedales y el agua. También presenta una serie de recomendaciones orientadas a que dicha producción sea compatible con el mantenimiento de las funciones que ofrecen los humedales y la preservación del recurso agua.

Biofuels are a response to the rapid depletion of fossil fuels and as a fuel which reduces the emission of greenhouse gases compared to fossil fuels. However, the increased use of biofuels from agricultural crops has led to a debate about the impacts of these products on the environment. Currently soybean accounts for over 60% of the cultivated area of the country and is the main crop for biodiesel production; making Argentina the world's fourth largest producer of biofuels and the largest exporter. This publication compiles and analyzes current information regarding expansion of soybean crop in Argentina, as well as impacts on wetland ecosystems and water resources. It also presents a series of recommendations towards making soybean production compatible with maintaining wetlands functions and preserving water resources.

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ISBN 978-987-24710-8-8

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