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The strategic role of plant breeding in Uruguay: analysis through an agricultural innovation system framework

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The Strategic Role of Plant Breeding in Uruguay: Analysis Through an Agricultural Innovation System Framework

A report for the Global Partnership Initiative for Plant Breeding Capacity Building

Howard Elliott
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Foreword and acknowledgments

The Global Initiative on Plant Breeding (GIPB) commissioned a study to "develop a framework and supporting case study material that will inform governments, NARIs, development agencies and the private sector how they might invest in plant breeding systems (PBS) to improve efficiency and enhance impacts on productivity and profitability in the agricultural sector". The study team comprised three economists –John Lynam, Elon Gilbert and Howard Elliott – each of whom brings at least four decades experience in developing university and agricultural research systems throughout the developing world. The task was to use their experience with various frameworks and tools of analysis to derive lessons for investment strategies for six case study countries – Bangladesh, Ghana, Kenya, Malawi, Thailand and Uruguay – within each of which three or four commodity subsystems would be studied. A continuing dialogue among team members, experts in GIPB and consultants in a parallel study enriched the approach taken. The work could not have been done without the open cooperation of authorities and scientists in the case-study countries. As might be hoped from such a study, there has been a progressive refinement of the questions and the methodology as case-study experience has been shared. However, there was significant discussion about how to approach the field work in a systematic way in order to place general lessons and specific recommendations in their proper context.

This study analyses the efficiency and effectiveness of plant breeding in Uruguay in an innovation systems framework by treating the plant breeding system (PBS) as a subsystem of a larger and evolving agricultural innovation system (AIS) in Uruguay. The quality and efficiency of plant breeding activities *per se* are converted into impacts through complementary (or vertically integrated) activities of policy-makers, agronomists, seed specialists, formal and informal seed producers and growers. All of this takes place in an institutional and policy environment that determines the incentives for farmers to demand improved cultivars and the type of seed system that ensures their availability.

The author is grateful for the generous collaboration and support he was given by management and scientists of the National Institute for Agricultural and Livestock Research (INIA) in sharing their insights and facilitating contacts with their colleagues at Las Brujas and La Estanzuela. He expresses his special appreciation to Ing. José Silva, Manager of the Division of Technology Transfer and Communication and to Lic. Veronica Musselli, Coordinator of the Division of International Cooperation, for their continuous support throughout his visit. Ing. Carlos Rossi included the author in a field day organized jointly by INIA and the National Seeds Institute (INASE), where he was helped by many people from La Estanzuela. Ing. Pedro Blanco, Head of the Rice Programme, was generous with his time and documentation. The author benefitted greatly from the insights of Ing. Gustavo Blanco based on his service in many of the institutions studied and from Dr Daniel Bayce of the Camara de Semillas. The author is also grateful to

Dr Manuel Otero, Representative of the Inter-American Institute for Cooperation on Agriculture (IICA), and Dr Emilio Ruz, Executive Secretary of the Cooperative Programme for the Development of Agricultural Technology in the Southern Cone (PROCISUR), for their hospitality and help in understanding the broader context of the Southern Common Market (Mercosur) within which the Uruguayan innovation system operates.

Acronyms

ACA	Rice Growers' Association
AIS	agricultural innovation system
ANII	National Agency for Research and Innovation
ASTI	Agricultural Science and Technology Indicators
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CUS	Uruguayan Seed Chamber
EEMAC	Estación Experimental "Dr. Mario A. Cassinoni"
FFRAA	Fund for Financing and Reconversion of Rice Activity
FLAR	Latin American Rice Foundation
FTE	full-time equivalent
FPTA	Agricultural Technology Development Fund
GDP	gross domestic product
GIPB	Global Initiative on Plant Breeding
GMA	Rice Millers' Union
GMI	Ministerial Cabinet for Innovation
GMO	genetically modified organism
GNBio	National Biosafety Cabinet
IDB	Inter-American Development Bank
INASE	National Seed Institute
INIA	National Agricultural Research Institute
IPB	International Plant Breeders
IPR	intellectual property rights
LAC	Latin America and the Caribbean
LATU	Technological Laboratory of Uruguay
Mercosur	Southern Common Market
NAIS	National Agricultural Innovation System
NGO	non-governmental organization
PBS	plant breeding system
PBS/SS	plant breeding system/seed system
PEC	Protocol for Commercial Expansion
PPP	purchasing power parity
PROCISUR	Cooperative Program for the Development of Agricultural Technology in the Southern Cone
R&D	research and development
SS	seed system
UdelaR	University of the Republic
UPOV	International Union for the Protection of New Varieties of Plants
URUPOV	Uruguayan Association for Plant Breeders' Protection

Executive summary

This report on the strategic nature of plant breeding in Uruguay is an input to a six-country study of plant breeding and seed systems. Three countries in sub-Saharan Africa (Ghana, Malawi and Kenya) and two in Asia (Bangladesh and Thailand) covered a range of experiences, income classes, size of system and dependence on global markets. Uruguay was proposed by the study team for the contrasts it presents with the other countries. It is a small country, bordered by two of South America's agricultural giants – Brazil and Argentina – that are also partners in the Southern Common Market (Mercosur). As such Uruguay is continuously faced with both financial and technological spillovers. Changes in Argentina's fiscal policies towards agriculture have stimulated waves of investment in Uruguay by Argentinian farmers, who bring with them their technology and seeds. Brazilian investment in the milling industry has the potential to change the structure of the industry and its marketing strategy. This report on the Uruguayan agricultural innovation system is presented as a standalone report to make it useful for discussions within Uruguay. By adopting an agricultural innovation system (AIS) perspective, it serves to highlight several issues in a cross-country comparison for eventual synthesis.

The report begins with an abbreviated description of the AIS framework that highlights the way that policy, institutions and the external environment interact with the suppliers and users of agricultural knowledge and technology to produce a pattern of innovation. An innovation system framework can help identify the strengths and weaknesses of an implicit innovation system; the policy and economic environment, the public and private institutions engaged in production and use of knowledge and the channels by which farmers and agro-industry access and use knowledge and technology. Plant breeding, which falls largely in the public sector, is a strategic part of Uruguay's response to changes going on around it.

After introducing the key components of the AIS, the paper reviews the structural changes currently going on in Uruguay, including 1) changes in the relative contribution of livestock and cropping to the economy, 2) the adaptation of the rice–pasture system and 3) the development of new rotations to maintain soil fertility with the expansion of soybean cultivation.

Uruguay has historically been an important exporter of livestock and dairy products, favoured by its temperate climate and its ease of access to foreign markets. It has a long history of agricultural research going back almost 100 years, while the current National Agricultural Research Institute (INIA) is celebrating its 20th year. Thanks to its compact size, good road and port infrastructure and administrative capacity, Uruguay has been able to manage policies that create value in the economy and facilitate change. Uruguayan policy has been sensitive to external markets and the opportunities they create for the country's products. Differentiated policies in rice and soybean are but one case in point. There is close integration of research with organized farmers and agro-industrial value chains and research has been supported by an earmarked tax on agricultural production. Plant breeders' rights are recognized and a public–private system is in place to ensure that royalties (*valor tecnológico*) are paid to the holders of plant breeders' rights even on farmer-retained seed. Several of INIA's programmes receive a royalty for their varieties in addition to their share of the research tax that goes to INIA centrally.

This report focuses mostly on the rice subsystem, although observations are made for comparison on wheat, barley, soybean and maize, commodities that are critical to understanding the transition going in Uruguayan agriculture. INIA has played the key role both in the breeding of national cultivars, which account for 95 percent of the varieties grown, and in the development of the crop management techniques that are responsible for high yields, environmental stability and the continued use of the rice–pasture system. Uruguay is the world's seventh largest exporter of rice and has achieved success in markets that require quality grain free from genetic modification.

The integrated structure through which the rice milling industry works with research, selects varieties for multiplication, discusses varieties and negotiates preplanting prices with rice growers has brought stability and some conservatism to the sector. The system may come under stress due the purchase in 2007 of Saman, which accounts for 50 percent of the Uruguayan milling industry, by a large Brazilian firm, Camil. As of the time of writing, the industry has maintained the status quo. The takeover could represent a market extension acquisition for the parent company to go after European and middle-eastern markets that exclude genetically modified organisms (GMOs) or it could open the way to refocusing Uruguayan production on the Brazilian market, with significant implications for varieties and technologies. The important thing is that the research system has the capability to support change.

Related changes are taking place in wheat, barley, maize and soybean. The rapid growth of the soybean area is made easier by Uruguay's small share in global markets, the investment by Argentinian investors and still-profitable soybean prices. While Uruguayan production can grow without disrupting markets, it is generally true that good harvests in Uruguay are matched by good harvests in Brazil and Argentina, and global prices can be volatile. For the moment, attractive soybean prices create a demand for other crops that fit in the soybean–cereal rotation. Each value chain has its own characteristics. Demand for malting barley is linked to industrial demand, and the purchase of Uruguayan brewers and malters by Ambev, a Brazilian subsidiary of Anheuser-Busch, may create global markets. The plant breeding strategy for barley has focused on malting quality and disease resistance. Wheat is the object of an INIA-growers programme, Grupo Trigo, which must address disease, productivity and quality issues if Uruguay is to export to a global market. In maize and soybean, Uruguay has ceded the breeding role to the private sector. In maize, INIA has shifted its attention to a niche market for family farmers unable to invest at the scale required for genetically modified hybrids, while in soybean Uruguay is an adjunct to the Argentinian seed companies and unable to compete in processing with Argentinian crushers due to scale economies.

The institutional arrangements, the plant breeding problems and the cropping systems associated with these commodities must be understood in the light of supporting policies, institutions and regulations for protection of plant breeders' rights, biosafety and the certification of exports to countries that are intolerant of genetically modified crops.
The importance of both the public and private sectors in making this system work is clear.

This report elaborates several potential lessons. First, a small research system can still play a strategic role through plant breeding and associated crop management. In the Uruguayan case this is shown by an ability to devolve some activities to the private sector and to concentrate capacity in areas where it can produce technologies suited to the local situation. The rice–pasture system is a clear case which is productive, economic and environmentally acceptable. Second, close integration with the private sector ensures relevance and user funding for research. This closeness may produce conservatism in the industry, in the form of a reluctance to change varieties. Third, research has to be looking ahead to future challenges. In the case of rice, INIA's research on Clearfield hybrid rice aimed at developing high-yielding non-GMO varieties is far-sighted. Finally, a small country may have an advantage administratively in monitoring biosafety, protection of breeders' rights and improving the use of certified seed. Investment in reliable institutions is an essential part of a functional plant-breeding system.

1. Introduction and approach

This study employs an agricultural innovation system (AIS) approach (World Bank 2006a; Elliot 2008) as a means of analysing the contribution that research (and plant breeding in particular) makes to agricultural innovation in Uruguay. It is a study of both the approach and the Uruguayan AIS. Annex 1 elaborates in greater detail the model AIS used to describe and analyse the Uruguayan AIS. Figure 1 illustrates the key elements of the system.

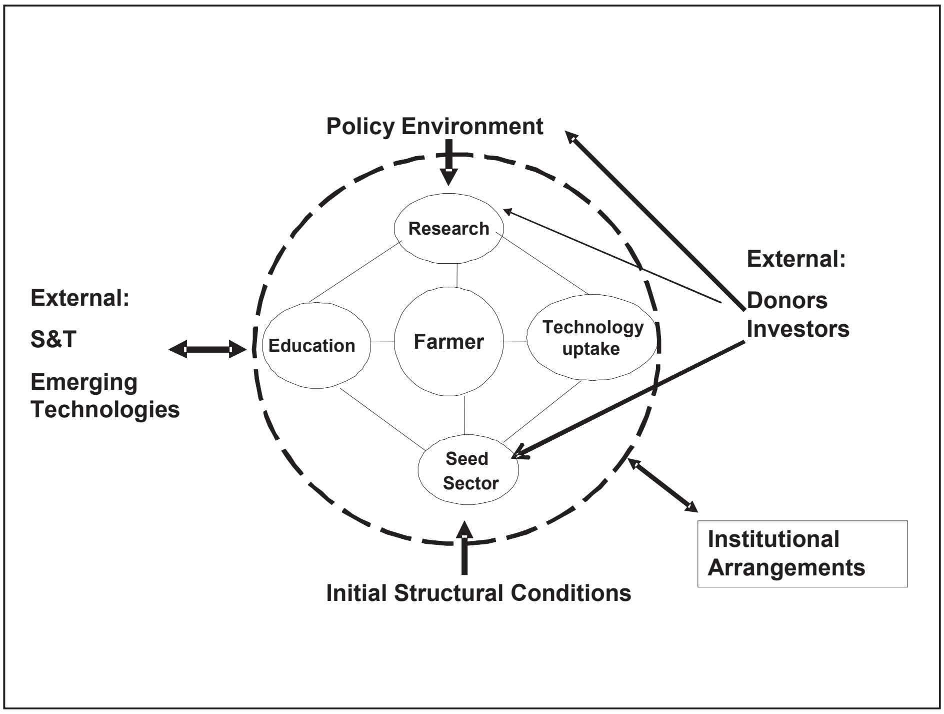

Figure 1. Evolution of key components and relationships in an agricultural innovation system. Source: Adapted from Elliott (1988).

A system is defined as a set of parts coordinated to achieve a common objective. It is defined by its objectives, components, management, resources, and environment. Treating the plant breeding system as part of an innovation system, we can specify the elements of the system, as follows:

Objective: A non-controversial statement might be to generate and ensure the adoption and use of plant-breeding outputs to improve productivity, sustainability and welfare of producers.

Components: Farmers, research organizations, educational institutions, technology transfer agents (extension, non-governmental organizations (NGOs), crop insurance, credit suppliers) and the formal and informal seed sectors. In addition, there are organizations and institutional arrangements through which components interact at each level and across levels of decision-making.

Management: the means of coordination of policy, resources and the various components.

Resources: human and financial resources and how they are allocated are a measure of the functionality of the system.

Environment: the initial structural conditions and the sources of external shocks. These may be policies that affect the level, direction and relative prices of inputs and outputs of the system (incentives) or external scientific advances that change the game for Uruguayan producers.

Since a specific objective of this study is to look at the strategic importance of plant breeding within the AIS, Figure 1 explicitly includes the seed system as a component with linkages to the rest of the system.

The AIS framework (World Bank 2006; Elliott 2008) can be used:

- as a diagnostic tool to help rapidly identify system constraints;
- as an aid in the design of best fit solutions to constraints rather than blind application of best practices from elsewhere;
- as a means of fostering a self-aware system that can become self-correcting.

How far along this spectrum of uses one goes is often determined by the confidence analysts have in lessons drawn from prior experience and ability to use the diversity of experience to design best fits.

An innovation system can be described at various levels: national, local, district, commodity or programme. It is possible to have examples of strong programmes within generally weak institutions or components of national systems operating at different levels of technical and managerial strength. There may be missing mechanisms or resources that prevent a needed connection among otherwise functioning organizations. It is common to find that researchers and extension agents get along well at the local level but there may be organizational conflicts at the national level. Scientists in Universities and semi-autonomous research institutes may collaborate but there are often limited resources or institutional arrangements for mobility between research institutes and universities.

The AIS framework underlines the fact that innovation is a messy process. It involves experimentation, learning by doing, often new institutions and new actors and linkages among actors that are allowed to grow in response to changes in the environment. The continuing issue of underinvestment in research and development ("get the resources right") was complicated during the decade of structural adjustment ("get the budget right") followed by a decade of liberalization ("get the prices right"). With rapidly changing challenges and opportunities such as global commodity price spikes and collapses, climate change and regional polices, countries have to "get the system right". This requires incentives, policies and institutional arrangements that prove effective in determining strategy and converting it into action. The flexibility of organizations to learn and adapt to change is critical.

The first step in getting the system right requires not only an evaluation of the adequacy of expenditure on research and development (R&D), the composition of expenditure and of human and institutional capacity but these questions have to be placed in the context of "capacity for what?"

In addition to this Introduction, there are three sections and four annexes in this report. Section 2, Overview: A national agricultural innovation system, describes key relationships in the Uruguayan AIS at the national level. It describes and analyses the essential coherence of the system at the macro level using published information and data sources. It begins with the recent transformation of the agricultural sector in its global and subregional context. This is followed by an outline of the key organizations and institutions involved in the AIS, and observations on their functioning as a system. This draws on the recent profile on Uruguay by Stadts *et al*. (2008). Beginning with the agricultural context helps to explain the choice of commodities that are compared for insights into the working of the AIS at a subsector level. Innovation systems approaches often end by focusing on successful value chains and we are interested in whether an approach that looks across value chains is also useful.

Section 3, The knowledge institutions, provides information on INIA and the University of the Republic (UdelaR) as the two organizations that account for most of the agricultural science, technology and plant breeding activity in Uruguay. The private sector does little plant breeding research as such in Uruguay. They do introduce lines developed outside into national evaluation trials carried out by INIA and the National Seed Institute (INASE) under a framework agreement between the two institutions. UdelaR participates in a project carried out by INIA and INASE to study genotype–environment interaction in *Festuca*, ryegrass, red clover and *Lotus* cultivars, a project funded through the Agricultural Technology Development Fund (FPTA)–INIA competitive research grant system. Finally, while not doing agricultural research *per se*, the Technological Laboratory of Uruguay (LATU) carries out scientific analyses, organizes innovation clusters and certifies imported and exported food products.

Section 4, The seed system, synthesizes information from various sources on the changing structure of the seed industry, which has been an important concomitant occurrence if not a driver of the agricultural transformation.

Section 5, The rice subsystem: Linear or innovation model?, deals with a successful integrated commodity subsector. Because of its importance in the economy and its research success, rice receives the most attention in this study.

Section 6 compares four commodities – maize, wheat, barley and soybean – and highlights particular issues affecting these crops. The limited role that national institutions have accepted in maize, in the face of massive imports of hybrids, is notable in comparison with the other crops in the study. The recent explosion of soybean production is part of a wider transformation of the agricultural sector in which annual crops are of growing importance relative to livestock production.

Section 6 looks horizontally across the commodity subsectors and vertically down the commodity chain from policy to satisfaction of final demand and highlights the implications for institutional capacity building and demands for plant breeding.

2. Overview: A national agricultural innovation system

Uruguay serves as a case study of use to countries with more that one of the following characteristics: 1) a small, open economy with large neighbours (e.g. Argentina, Brazil); 2) strong export orientation in staple commodities (e.g. rice); 3) participation in regional arrangements (the Cooperative Program for the Development of Agricultural Technology in the Southern Cone [PROCISUR], Mercosur, the Latin American Rice Foundation [FLAR]); 4) co-evolution of the public and private sector with differentiated strategies by commodity subsector; and 5) the need for a national policy to deal with direct foreign investment in the agricultural sector and its impact on policy.

Uruguay was initially included in this comparative study of six countries and four commodity subsectors for the lessons that might be found about 1) the options open to small countries to chart a national strategy; 2) the evolution of the plant-breeding function within different technologies; and the 3) the strategic role that organization of the research and seed systems can play.

2.1 The context for agricultural innovation

The section places Uruguay in the context of the Mercosur region in relation to its relative scientific and economic level of development; its participation in the regional AIS; and its strategy for research in support of agricultural development. For the Uruguayan experience to provide lessons for other countries, we will be looking for paths that Uruguay has travelled and whether they can serve as roadmaps for others. The reference period goes back to 1990, which was the date of creation of INIA, and permits the trajectory of research to be traced through several external shocks.

Rather than a long introduction with tables and graphs, we will characterize the Uruguayan situation by a number of stylized facts to be corrected where better information is available.

Transformation over the last 20 years

Uruguay is a stable, democratic, upper-middle-income country with a relatively well-educated population. The Uruguayan economy has been transformed structurally and institutionally over the last two decades. In 1990, for example, Uruguay was not included among upper-middle-income countries; it now ranks not only as an upper-middle-income country but among the top six countries of Latin America. Production of soybeans, wheat and barley has grown rapidly since the recovery in 2003, and some pasture has been converted to cropland. This has led to a small increase in the share of agriculture in gross domestic product (GDP), from 7 percent in 2000 to 11 percent in 2008. Whereas agricultural research was considered relatively weak in the late 1980s, INIA has recently been described as an “island of excellence” in the innovation scene in

Uruguay (World Bank (2006) Uruguay: Innovation Project profile”). Its research system is considered to be strong and well-linked to the private sector.

Recovery from crisis and current level of development

Uruguay suffered from the Latin American crisis and recession of 1998–2003 (Hausmann *et al*. 2005), during which GDP fell 25%. Recent growth shows that the country has recovered but debt load limits the expansion of public expenditure as the country seeks to re-establish social welfare services and education. In 2008, nominal GDP per capita was US$8 260 (US$12 540 purchasing power parity [PPP]), compared with an average of US$6 780 and U$10 309, respectively, for Latin America and the Caribbean (LAC) as a whole (World Bank 2010).

Open economy, good business environment and growing regional bloc

Uruguay has a favourable reputation as a place to do business. It recently ranked sixth out of 12 LAC countries, behind Chile, Brazil, Trinidad and Tobago, Mexico and Colombia but ahead of Costa Rica, Peru, Panama, Argentina, El Salvador and Dominican Republic (LAVCA 2009).

Uruguay’s tariff regime is less protectionist than average for a LAC country. Its membership in Mercosur has created a larger market for its products, some of which benefit from the common external tariff (e.g. dairy). However, meat and wheat compete with established exports from Brazil and Argentina. Over the last decade Uruguay has been diversifying its exports. Exports to Mercosur countries have fallen from 43 percent in 1991 to 24 percent in 2009, while exports to the European Union now account for 24 percent of Uruguay’s exports and those to the North American Free Trade Agreement (NAFTA) countries account for a further 20 percent. Exports to China and Russia are also growing.

Uruguay does not have a large national financial sector, with the result that it is subject to large capital movements from Argentina and Brazil. Policy changes in Argentina have affected Uruguay, particularly in the agricultural sector where Argentinian farmers and companies have moved into Uruguay because of cheap land and favourable export opportunities.

Structural change in the agricultural sector

Recent trends in production of key commodities demonstrate that the agricultural sector has not just recovered from the crisis but there is evidence of a structural transformation (Figure 2).

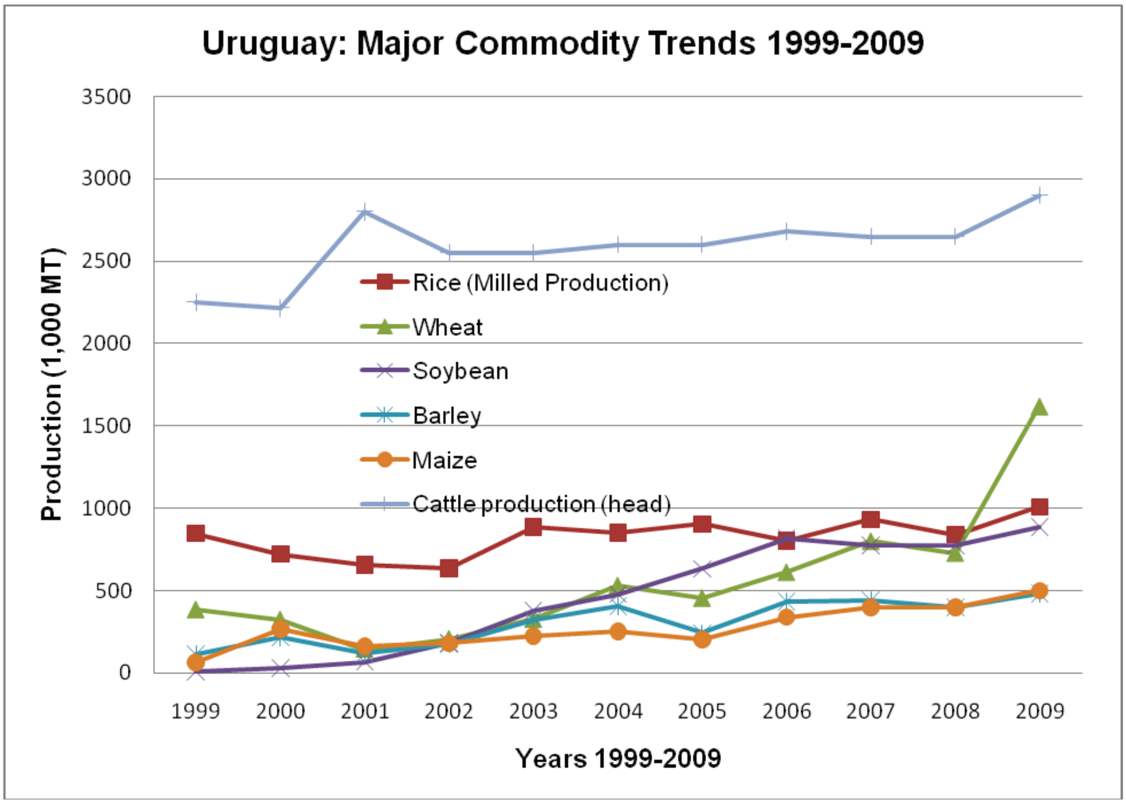

Figure 2. Production of major agricultural commodities in Uruguay, 1999–2009.
Source: USDA statistics.

The stylized facts that are highlighted in these recent trends are as follows:

- The rice sector continues to be a mainstay of Uruguayan agriculture. It suffered relatively less than wheat during the crisis years (2000–2003) but has shown a general rising trend over the whole period. The value of rice production exceeded the value of meat production for the first time in 2009.
- The spectacular rise of soybean production from less than 50 000 tonnes in the year 2000 to 885 000 tonnes in 2009 has been driven largely by Argentinian investors.
- The technical complementarity of wheat and barley with soybean production can be seen in the parallel rise of wheat and soybean production between 2001 and 2008. The rapid growth in the area planted to soybean, from 100 000 ha in 2003 to 540 000 ha in 2009 created opportunities for the expansion of wheat and barley in rotation with soybean. Recent attention is also given to sweet sorghum with potential for biofuel.
- The jump in production of wheat in 2009 reflects the very favourable prospects for sales of wheat in the Brazilian market at a time when Argentinian production stagnated and Brazilian production fell below demand.

- Barley grows in rotation with soybean but the market for malting barley is closely linked to the needs of the malt producers and an industry-controlled chain.
- The demand for maize as animal feed has grown, due in part to the conversion of some grazing land to cropland for soybean. While most meat is still range fed, an increasing share of meat is produced in feedlots. The rice–pasture rotation is important to the maintenance of the soil for rice production.

2.2 Policy and institutional changes

An innovation systems framework calls for the analyst to search for the co-determination of policies, institutional arrangements and technologies. One way to get an impression is to create a database of historical events categorized by nature of the event. Annex 2 lists key events in the evolution of agricultural innovation in Uruguay between 1869 and 2010. Key institutional events include the creation of INIA (1989) and, more recently, the purchase 50 percent of the Uruguayan rice milling industry (Saman) by a Brazilian firm (Camil). A structural change in the industry can imply possible changes in the demand by the industry for particular technologies. In this way, such a listing can be useful in highlighting the simultaneous determination of technology, policy and institutions.

The list, while rudimentary and only indicative of a methodology, is included as an example of a tool that can be easily created and improved simply by adding new entries as they are discovered in documents or cited as important events by policy-makers.

2.3 Institutional structure for research: The agricultural knowledge system

The institutional structure for agricultural research has being primarily associated with INIA and UdelaR. Together they account for three-quarters of the full time equivalents in agricultural research (Stads *et al.* 2008). The key features of the institutional structure are as follows:

- INIA's strategic and applied research is organized towards support of producers in eight commodity value chains and three cross-cutting strategic areas and is supported by cross-cutting technical units.
- The university concentrates on didactic (for purposes of teaching) and discipline-based research for generation of knowledge. There work on plant breeding but academic staff from botany, soil sciences and microbiology collaborate across disciplines in research projects.
- There has been a growth of capacity and average level of qualifications in both INIA and UdelaR.

- Through its earmarked funding and its mandate to serve the productive sector, INIA has received approximately 60 percent of funds allocated to agricultural research. Some of this funding goes through competitive funds to university researchers who carry out research of interest to INIA and there are funds for direct collaboration.
- Uruguay is unique in that the number of full time equivalent researchers working in livestock (43 percent) exceeds that for crops research (at 25 percent).

There is scope for improved collaboration between INIA and UdelaR. World Bank (2006b) identified INIA as an "island of excellence" and some faculties of UdelaR as "isolated cases" of excellence while making a more general statement about the need for more investment and coordinated development of the scientific base:

> There is a need to scale up these interactions and to make them more systematic and effective. Inadequate incentives by research institutions, constraints imposed on researchers within public institutes, and low private sector demand for knowledge services have all contributed to weak patterns of cooperation. In turn, low levels of collaboration translate into low labor mobility between the public and private sectors resulting in limited diffusion of knowledge which sets the innovation system in a vicious circle of low effectiveness and limited capacity to turn research into innovation.

National Institute for Agricultural Research

The National Institute for Agricultural Research (INIA) was created in 1989 as a public non-state entity with four basic characteristics: autonomy, decentralization, integration of the public and private sectors and link to the state through the Ministry of Livestock, Agricultural and Fisheries. It brought together national and regional interests through a mixed governance structure. At the national level, the governing council includes representatives of the executive and the private sector. At the regional level an advisory council in each experiment station with representatives of both the public and the private sector supports the research leadership. The choice of a public but non-state legal personality was designed to provide autonomy in resource management and a more private-sector-like management. Decentralization was based in five regional directorates located in the five experiment stations: Las Brujas, La Estanzuela, Salto Grande, Tacuarembó and Treinte y Tres.

INIA has eight commodity programmes, three thematic/cross-cutting programmes and six technical units. See Annex 3 for further details.

University of the Republic

The University of the Republic (UdelaR) contributes to agricultural research primarily through its Faculty of Agronomy, its four experiment stations (Estación

Experimental Faculdad de Agonomia en Salto, Estación Experimental “Dr. Mario A. Cassinoni” [EEMAC], Paysandú, Estación Experimental “ Prof. Bernardo Resoengurtt”, Cerro Largo and Centro Regional Sur) and its two experiment fields located in Migues, Canelones, and Libertad, San José. Since their function is to train professional agronomists their research is didactic or of disciplinary interest to the professors working in departments organized by scientific field. Based on an analysis of the lists of projects funded and contracts on the websites of the university’s research stations, the work is largely projectized, time bound and disciplinary in nature.

Teachers collaborate in projects across disciplinary lines and specialists from the university collaborate with INIA in specific ways, such as the study of genotype–environment interactions in grasses and forage crops previously mentioned. UdelaR has also collaborated with the Rice Growers’ Association (ACA) and the University of California (Davis) to develop a simple test of the environmental safety of irrigated rice (Carlomagnot *et al.* 2010). This has led to a common recognition that the university does work that contributes to plant breeding but it does not engage in plant breeding *per se.*

Increasingly the opportunity arises for university and INIA specialists to work together in biotechnology in support of plant breeding. An example of such opportunity is a project on durable resistance in barley involving EEMAC, INIA, the International Center for Agricultural Research in the Dry Areas (ICARDA) and universities in Mexico, Peru and the United States. The project is characterizing the genetic diversity in varieties used in Uruguay and mapping the genetic regions and alleles associated with desirable phenotypic, morphological and agronomic qualities for the malting industry. It is funded under FPTA-INIA for contract research and competitive grants.

Financial support to agricultural research

The most recent data on staff and financial investments by various sectors has been recently published by the Agricultural Science and Technology Indicators (ASTI) Project run by IFPRI (Stads *et al.* 2008) (Table 1).

Table 1. Composition of public agricultural research expenditures and research staff in Uruguay, 2006.

	Total spending				**Share**	
Type of agency	Current pesos (U) (million)	2005 Pesos (U) (million)	2005 International PPP dollars (million)	Total research staff (FTE)	Spending (%)	Research staff (%)
INIA	507.4	475.1	35.8	142.0	59.9	35.6

Other government (6)	110.6	103.5	7.8	69.8	13.0	17.5
Non-profit agencies (4)	26.0	24.3	1.8	17.2	3.1	4.3
Higher education (9)	203.8	190.8	14.4	170.4	24.0	42.7
Total (20)	847.8	793.7	59.8	399.4	100.0	100.0

FTE: full-time equivalents.
The numbers in brackets indicate the number of agencies included in each category.
Staff in "Other government" agencies devote 20–50 percent of their time to research (for a total of 698.8 FTE). Staff employed in four non-profit agencies spend between 30 and 80% of their time on research.

Stads *et al.* (2008) summarize the salient points about R&D in Uruguay as follows:

- Research expenditure (2006) as a share of agricultural GDP is close to 2 percent, which is much higher than in other Latin American countries.
- Uruguay is also unusual in that its livestock sector and livestock research have traditionally dominated both production and research expenditure.
- Uruguay's funding structure is unique in that INIA, its national agricultural research institute, receives the proceeds of a tax levied on the total sales value of agricultural commodities.
- Collaboration is good with international, regional and other national agencies. The FPTA receives 10 percent of the funds from the agricultural commodity tax for collaborative research with other organizations.
- Uruguay employed roughly 400 FTE researchers at a cost of US$60 million (in 2005 PPP prices).

In summary, Uruguay has a small but reliably funded research structure with mechanisms to encourage collaborative efforts. It also participates in regional programmes through PROCISUR.

These figures do not include funding that is becoming available under the new National Agency for Research and Innovation (ANII), created in 2007 (Law 18.084). Following the creation of a Ministerial Cabinet for Innovation (GMI) in 2005 the government outlined its main policy thrusts in science, technology and innovation in 2007. These were: 1) public policies and institutions for science, technology and innovation; 2) capacity building; and 3) transfer of technology through public–private linkages. ANII receives support from the European Union, the Inter-American Development Bank (IDB) and the Centre for the Development of Industrial Technology (CDTI), Spain. In addition to its growing role in funding, ANII has allowed salary supplementation for researchers in all areas qualifying for its projects.

Before completing the macro perspective, it is necessary to look at the link between the research/plant breeding system and the seed sector (PBS/SS).

2.4 Policy and regulatory environment for plant breeding

The following institutions or political decisions have had important implications for the Uruguayan agricultural sector in general and plant breeding in particular.

National Seed Institute

The National Seed Institute (INASE) was created in 1997 (Law 16811) to promote and contribute to the development of seed activities encouraging the use of appropriate quality seed, whether foreign or domestic. Included in this is the protection of genetic discovery and authorizing proprietary titles and support for the export of seed. The institute advises the government on matters of seed policy. INASE's mandate includes:

- evaluating cultivars for inclusion in the national registry;
- maintaining official seed laboratories and certifying private seed certification laboratories;
- controlling seed production according to established norms;
- handling and resolving issues relating to imports and exports of seed;
- determining and applying sanctions for infractions of regulations.

With the upsurge in demand for GMO evaluation trials and the painstaking protocols for evaluating transgenic materials prescribed by the Risk Management Committee of National Biosafety Cabinet (GNBio), INASE will see an increase in its work.

INASE is funded by fees for services, an annual government subvention and other donations or legacies. It is affiliated with all the major international seed organizations (International Seed Testing Association, International Union for the Protection of New Varieties of Plants [UPOV], the Organisation for Economic Co-operation and Development and the Association of Seed Certification Agencies (AOSCA).

National Biosafety Cabinet

The National Biosafety Cabinet (GNBio) was created by Decree 353/08 of 21 July 2008 [modified 3 November 2008], which established a regulatory framework for "the regulated co-existence between modified and non-modified plants". This was linked to the broader development framework called "Productive Uruguay."

The decree created five bodies:

1. GNBio, responsible for ministerial approval;
2. the Risk Management Commission (CGR), responsible for technical implementation;
3. Evaluation of Biosafety Risk (ERB), responsible for high-level evaluation of the risk of each GMO release;
4. the Committee for Institutional Articulation (CAI), responsible for harmonizing institutional protocols applied in each sector;
5. the Consultative Committee on Biosecurity (CCB), responsible for ensuring consultation with a broad range of stakeholders, including specialized institutions, the private sector, universities and civil society.

Uruguayan Association for Plant Breeders' Protection

The Uruguayan Association for Plant Breeders' Protection **(**URUPOV**)** was created in 1994 to promote the diffusion of new varieties, protect the rights of owners of plant breeders' rights and eliminate seed of unknown origin from the market. It oversees a registration system through which plant breeders receive a royalty from sales of their seed and URUPOV collects royalties on farmer-saved seed on behalf of the registered breeder. Uruguay is a small country with well-developed markets and processing, hence it is relatively simple to administer the system. URUPOV's 32 members include all the major seed importers and exporters (members of the Uruguayan Seed Chamber, CUS). Similar legislation in Argentina provides for payment of royalties to INIA for its varieties used there.

Quality control by the private sector

Uruguay benefits from the existence of 12 private-sector laboratories that are accredited to certify seed and a further 42 seed laboratories distributed throughout the country that are capable of contributing to evaluation methodology. For example, IPB Semillas developed an accelerated aging vigour test that was more sensitive than the standard germination test used to determine physiological quality in seed lots for birdsfoot trefoil (Artola and Carrillo Castañeda 2005).

2.5 The seed industry as part of the broader innovation process

This section describes the development of the seed industry in Uruguay as part of an evolutionary process that is linked to a broader innovation process going on in the Southern Cone. As a small, open economy Uruguay is strongly affected by technical, economic, financial and institutional developments in Argentina and Brazil. Specific examples are detailed below.

Technical innovation

Research in Embrapa that turned the Brazilian savannah (*cerrados*) into a soybean powerhouse and the widespread adoption of genetically modified soybean in Argentina have made the Southern Cone a major player in the global market. The technology and the institutions cross the border into Uruguay. As Beddow *et al*. (2009) argue, Latin America and China were the only regions of the world where the rate of growth of agricultural productivity increased over the period 1990–2009.

The Uruguayan agricultural sector has seen two key structural changes in which research played a role: in 2009 the value of rice exports exceeded that of meat for the first time; and the area planted to soybean grew from 100 000 ha in 2003/04 to 540 000 ha in 2009/10 (USDA/FAS, various years).

Research has critical role in developing the rotations (soybean–wheat or barley and rice–pasture) that supported this growth. Crop–pasture rotations are unusual elsewhere in the world but have been the predominant cropping system in Uruguay since the 1960s. Half of crop-producing farms and a quarter of dairy farms have adopted no-till practices in their crop–pasture rotations. This requires sophisticated management but halves fuel and agrochemicals usage, thereby increasing profitability (Garcia-Préchac *et al.* 2004).

Economic policies and financial movements

Uruguay's GDP fell by a quarter during the financial crisis of 1999–2002. In recent years, considerable numbers of Argentinian farmers moved to Uruguay because of lower land prices, more favourable fiscal policies and stability, promoting rapid growth in soybean production.

Structural changes in the industry

In certain key sectors, in particular rice and malting barley, there is a close integration between the milling industry, seed production and seed growers. Since product quality is of critical importance, the industry determines the varieties it will purchase, contracts growers to produce them and provides seed at a subsidized price to ensure farmers use certified seed. The recent sale of half the rice milling industry to the largest Brazilian rice company might be considered a structural change in the industry. So far it does not appear to have interfered with the contract system in place.

2.6 Structure of the seed system

In this section, we identify the key actors in the seed system and the interactions among them as they relate to key commodities and production systems. The discussion goes beyond individual commodities because the role of the key institutions in major crop–livestock and cropping systems is critical. The research system (INIA, UdelaR) and the regulatory bodies have already been discussed above.

Uruguayan Seed Chamber

The Uruguayan Seed Chamber (CUS) is an association of 32 companies involved in the production and marketing of seed in Uruguay. They are also the largest exporters of grain from Uruguay.

CUS is linked to the principal representative bodies in agriculture. It is a member of the International Seed Federation, the Seed Association of the Americas, the Governing Board of INASE and the Managing Council of the National Wheat Roundtable.

Many of the 32 member companies have been acquired by multinational seed, chemical, or biotechnology companies (see Annex 4).

The stylized facts are as follows:

- The major players in the global seed industry are all represented in Uruguay through acquisition of local seed companies.
- International trading, seed and input companies are engaged in two-way trade: provision of inputs linked to their branded seed and marketing of Uruguayan exports.
- Rice and malting barley are special cases where the milling industry has assumed the role of integrating the value chain and negotiating an incentive structure that guarantees both supply and quality.
- Uruguay is sensitive to changes in the economic climate in Brazil and Argentina:
    - Fiscal policies in Argentina have driven investors to take up soybean and wheat cultivation in Uruguay.
    - Expansion of Brazilian rice demand has driven Camil (second largest Brazilian miller concentrating on its local market) to purchase both Uruguayan and Chilean companies producing for the global market. By industry accounts this is to help Camil become a large player in international markets.
- International companies play an important role in providing forage and pasture seeds in Uruguay.

The role of the INIA Seed Unit in this process is discussed below.

The INIA Seed Unit as bridge between research and seed production

INIA's Seed Unit handles more than 20 species and 50 varieties. It is responsible for varietal maintenance, administration of commercial sales, protection of cultivars and control of quality of all seed offered by INIA. Demand for publicly owned varieties is highly variable, and in some cases INIA researchers have been taken off their research tasks to help with seed production.

2.7 The trade deficit in seed

Uruguay is a major exporter of agricultural products yet imports large amounts of seed (Table 2).

Table 2. Uruguay's trade balance in seed, 2008 (US$).

	Imports	Exports	Balance
Summer crops			
Rice	185 402	31 520	(153 882)
Soybean	15 657 906		(15 657 906)
Maize	12 387 187	141 918	(12 245 989)
Winter crops			
Wheat	5 851 886	12 870	(5 839 106)
Barley	38 426		(38 426)
Forage crops			
Alfalfa	876 650		(876 650)
Festuca	939 145	209 084	(730 061)
Lotus	1 185 076	383 808	(801 268)
Ryegrass	528 390	817 393	289 003
Trifolium	1 024 908	806 858	(218 069)

Source: INASE (2009).

The trade balance in rice seed is minor compared with the value of the crop. Uruguay produces almost all its seed in a tightly integrated chain. Imports are predominantly of Puitá INTA CL, a Clearfield variety imported by BASF Uruguay from Argentina.

Two genetically modified crops, soybean and maize, show a large net deficit in trade. Most of this deficit is due to imports of seed from Argentina, where international seed companies have a strong presence in breeding and seed production.

The large deficit in wheat seed sales is largely due to trade with Argentina.

Given the importance of livestock and the increase in planted forage crops (grasses and legumes), the forage subsector could be an area of future development for the domestic seed industry. Uruguay has a positive trade balance in grass seed with Australia, Canada, Israel and Spain and in forage legume seed with Germany, Netherlands, South Africa and the United States. Currently, only 15–20 percent of livestock graze on planted pastures. However, planted pasture will become more important as annual cropping increases on land previously under long-term pasture.

The fact that Uruguay is importing seed for a commodity that it exports commercially does not mean that import substitution in seed production is required but it is an opportunity to rebalance the system.

In December 2008 PROCISUR and INIA organized a workshop titled "Challenges facing the seed industry in Uruguay: lessons from the Chilean experience". Chile is the seventh largest exporter of seeds in the world and the largest in the southern hemisphere; Uruguay ranks 55th. The size of Chile's internal market for seed in 2007 was around US$120 million, compared with Uruguay's at US$70 million (Schindler 2008). The top three commodities by area for Chile's internal market are wheat, maize and horticultural crops. Thirty to 40 percent of wheat seed is considered "illegal" (non-controlled).

The Chilean Seed Growers Association has 66 members, 52 national and 14 foreign. Chilean firms account for about 47 percent of exports. The sector is governed by the Seed Law (1977), Breeders Rights on New Plant Varieties (1994) and Resolution 1523 (2001) on norms for the introduction of living modified plant materials or propagation. Chile applies a policy of multiplication of GMOs for export purposes only (Secretariat for Agriculture and Livestock resolution 1523 [2000]).

Maize accounted for 53 percent of seed exports in 2007 by value, followed by vegetables (29 percent) and flowers (6.5 percent). Main markets in order of value were USA (60 percent), Netherlands (10 percent), France (8.5 percent) and Japan (5 percent). Trade in these markets is evidence of high standards of sanitary and phytosanitary control in Chile.

The success of the Chilean seed industry is attributed to the following structural factors (Aparicio 2008; Schindler 2008):

- Counter-seasonal production
- Good climatic conditions: low temperatures in winter, warm and dry summers; production under irrigation, freedom from principal diseases
- High yields: production under irrigation
- Natural barriers to disease transmission
- Phytosanitary history
- Entrepreneurial capacity: high technical level and serious response to export challenge.

In addition, the industry is assisted by the following commercial factors:

- Legal framework: Seed Law, international standards, UPOV protection
- Link to international seed organizations: standards and plant breeders rights (UPOV)
- Certification standards: certification accepted by all EU countries (1980); Member of Association of Official Seed Certifying Agencies (1998) facilitating access to US and Canadian markets
- Profitability: includes provisions favourable to foreign private-sector investment
- Known prices: negotiations preseason
- Financing programmes: ProChile Fund for Agricultural Exports
- Technical assistance: responsiveness of public sector to industry needs; support from INIA
- Specialization: in a few major areas

There are some notable differences between Chile and Uruguay. First, Uruguay lacks the national barriers to disease and pests that are part of Chile's comparative advantage. Can it turn its disadvantages into advantages? Uruguay is a hot spot for some problems. Research investments that overcome these problems could favour INIA varieties in export markets. INIA is already testing some of its successful wheat varieties through Argentinian evaluation trials. Approval there would give access to the Argentinian market and exports to Europe. Research on cold tolerance in rice is central to FLAR's programme. Second, Uruguay does not have the strong monitoring capacity that Chile does, but INIA is working on georeferencing for traceability purposes in vegetable production. Third, in its favour, Uruguay has modernized its port facilities and has good transport facilities. Its legislation is favourable for private-sector foreign investment. Its domestic market is small, so specialization in some export branches would seem to be the only way to achieve scale and unleash potential entrepreneurs.

Thus, the Uruguayan PBS/SS has many things favouring its success, especially financial support, collaboration and supportive policies. The next section brings the analysis down to the level of a commodity subsector: the case of rice.

3. The commodity subsector analyses

This section examines horizontal linkages along the entire chain from research to final demand in the rice subsector. While it is common in innovation studies to caricature this as the old "linear approach," many integrated commodity subsystems have proven successful in creating new sectors and, as an analytical tool, it can point out points of stress. The approach also requires us to look at how subsystem needs are translated into decisions from the farm to the national level and the organizations through which they are made.

A major issue is whether many services (e.g. credit, input supply, bulking and storage) are provided across commodity chains or insulated in closed commodity chains. Policies that increase efficiency by facilitating the capture of potential economies across commodities are often dependent on higher level policy actions. The rice subsector, as a major contributor to national income, tax revenues and exports has spillover effect to the rest of the economy. We comment on how the agencies serving the rice subsector also serve other strategic commodity subsectors.

3.1 The rice subsystem: a linear or an innovation model?

In a rapid study that both explores methodological issues of rapid appraisal of plant breeding subsystems within agricultural innovation and attempts to capture the reality of a particular national system, certain trade-offs have to be made. In this case, the approach was to investigate the rice subsector in greater detail and then make some comparisons across other annual crops of growing importance: maize, wheat, barley and soybean.

General background: rice exports and the rice–pasture system

Uruguay is the seventh largest exporter of rice in the world, with exports accounting for 95 percent of total production. Its competitiveness in rice is based on quality, reliability of supply and opportunistic capture of markets. The national average yield is 8 tonnes/ha, one of the highest in the world. Almost all rice produced in Uruguay comes from three INIA varieties (El Paso 144, Olimar and Tacuari).

The commonest rice farming system is closely linked to livestock: after two years of rice production the land is sown as pasture for four to six years in order to renew the fields and provide grazing for cattle. This is considered to be a sustainable production system that minimizes requirements for herbicide, insecticide and fertilizer.

Availability of seed of forage crops is important for the pasture component of the rice–pasture system (Table 3). Temperate legumes are addressed by a regional programme of PROCISUR (Proyecto Lotassa). Fodere (2007) noted that Argentina, Chile and Uruguay have good availability of quality forage seeds, a well-established plant breeders' rights system and government institutions that are in general doing a good job. There is a demand for new cultivars of *Lotus* due to: the expansion of grain crops over better soils; greater rainfall variability; the strategic role of *Lotus* in long-term pasture mixtures for beef production; adoption of improved pasture management technology; increased use in marginal areas where alfalfa does not perform; mixture with fescue and cocksfoot to improve summer production; short-lived pasture phase in rotation with soybean and maize for silage; and soil improvement in crop–pasture rotations.

Table 3. Regional seed industry requirements for pasture legumes in temperate southern America in 2007.

Crop	Area planted (ha)	Seed (t)	No. of cultivars	Source, exports and research	% seed labelled
Alfalfa	5 million	10 000	350	80% seed consumption by US, Australia, Europe 20% of research is local	n.a.
White clover	1 million	1 200	25	25% imported, Good Uruguayan and Argentinian seed production	60
Lotus corniculatus	1.6 million	5 000	6 (2 widely cultivated)	All seed from region 100% research done in region. 80% from Uruguay Some exports to US, Europe	20
Lotus tenuis	200 000	500	6 (2 widely cultivated)	All seed produced and mostly used in Argentina	20
Lotus subbiflorus	100 000	500	1	Single cultivar from Uruguay	20

				All research done locally All seed produced in Uruguay	
Lotus pedunculatus	20 000	50	2 (from overseas research)	Seed produced in region, Used mainly in northeastern Uruguay	90
Ryegrass (annual) (Lolium multiflorum)	n.a.	n.a.	4 foreign 4 domestic	INIA and Wrightson (NZ) each hold rights to 3 cultivars; Lebu (Uruguay) and Agritech (Holland) each hold rights to one.	n.a.

Sources: Fodere (2007); INASE website.

Uruguay and quality niche markets for rice

Uruguay has good roads and short distances from production areas to good port facilities, resulting in low transport costs. All major international traders are present to exploit global market opportunities. Uruguay's strict maintenance of GMO-free rice production has allowed it to gain new markets in Europe and the Middle East (Table 4).

Table 4. Exports of Uruguayan rice by country, February 2009.

Country	% share
Iran	21
European Union	23
Brazil	12
Peru	10
Iraq	8
Senegal	4
Benin	3
Venezuela	3
Angola	2
Others†	15

Source: ACA. March 2009. Arroz. Table 3 p.7

† Others: Albania, Argentina, Barbados, Belize, Bolivia, Cameroon, Canada, Cape Verde, Chile, Côte d'Ivoire, Dominican Republic, El Salvador, Ghana, Guinea, Honduras, Israel, Jamaica, Japan, Kuwait, Lebanon, Mexico, Puerto Rico, Russian Federation, Saint Vincent and the Grenadines, Saint Lucia, Syrian Arab Republic, South Africa, Turkey, United Arab Emirates.

Rice is a model of an integrated commodity subsector.

Objective of the rice subsector: maintain rice as a dynamic export crop

Uruguay has taken several strategic decisions that are constantly under review and negotiation to help it meet the challenge of maintaining rice as a dynamic export crop. Critical considerations include the following:

- Maintain a high level of quality and focus on the high end of the market.
- Even as the world's seventh largest exporter of rice, Uruguay's share of the market is not so large that expansion will provoke a decline in global prices.
- At the high end of the market, special traits, processing and packing become critical but maintaining high productivity (8 tonnes/ha) is necessary.
- A critical issue is degree to which Uruguay's current market position is linked to the rice industry's non-GMO practice. This practice is maintained by a coincidence of interests of the industry (exporters and millers) and rice seed growers and producers. INIA has played an important role in its success. In association with the millers, INIA has selected four lines to enter in the INIA-INASE National Network for Evaluation of Rice Cultivars. INIA decides what lines enter the network trials. Promising cultivars are advanced to a stage of validation on the basis of a joint decision by INIA, the Rice Millers' Union (GMA) and the ACA under the framework of an agreement for validation, final evaluation and release.

Components of the rice subsystem

This section highlights the role of particular actors in the rice subsystem.

GMA: Demand for rice expressed by the milling industry dominates the sector. The passage of half of Uruguay's milling capacity into Brazilian hands has not yet changed behaviour in the sector but may do so. GMA is also the major producer of rice seed. It prices seed at a very small margin over rice grain. More than 95 percent of farmers use certified seed of GMA's preferred varieties. Some ACA members also produce seed but have a small market share.

ACA: ACA operates a formal price negotiation system with preplanting contracts between farmers and the milling industry, with triggers for adjustment in case of exceptional price movements. This arrangement stabilizes the sector and reduces risks for growers and is seen by most observers as a strength of the Uruguayan system. However, as with any stabilization system, it may bias the sector towards conservatism.

CUS: CUS represents the import/export industry and ensures that exports of rice bearing its label are GMO-free and meet quality standards.

INIA rice research programme: The specific objectives and priorities of INIA's Rice Research Programme are to:

- develop varieties of grain with qualities demanded (large grain, niche markets) and gain experience with the Clearfield system and hybrids in association with the private sector (with potential for seed production for export to other countries);
- integrate management practices and use of climatic information to improve the quality of grain and use of resources;
- study the sustainability of mixed rice–cattle systems and develop indicators of physical, economic and environmental sustainability;
- define good management practices for rice to establish the bases for differentiation.

Policy environment

One advantage of being a small country is the closeness between government and producer, industry and civil society organizations. The Minister of Agriculture, at the opening of the crop year 2009, underlined several characteristics of the Uruguayan system:

- The ACA is "a well organized and serious syndicate that acted as the 'guarantor of the integrated system'".
- The fiscal burden on agriculture was between 5.5 and 6 percent whereas the fiscal burden on the rest of the economy was more than 30 percent. This was defensible because of the many contributions of the sector to the overall economy.
- Uruguay's rice has a good brand in international markets. It is known for its productivity, quality and for being environmentally friendly due to the rice–pasture rotation that reduces chemical use and does not damage water quality. Dissipation of agrochemicals is below EU standards and residues on grain are below the level of detection.
- Water and irrigation are principal themes: First, water should be viewed in a collective way and not as an individual resource. Fifty-five percent of water used in irrigation is from dams and 45 percent from natural sources (rivers, lagoons and lowlands). Electrification of rural areas is lowering the cost of pumping and maintaining competitiveness. Some of the mills also manage irrigation schemes that support growers and the sector calls for fiscal relief for private sector to finance and implement the needed investments.

Means of coordination of the rice subsystem

The sector is strongly integrated along the whole value chain by the mills but there are also other mechanisms that provide important linkages among research, users and policy-makers. The GMA-ACA contract negotiations are the most important coordination mechanism.

The way in which the millers and the rice producers negotiate an annual contract covering price, varieties, and trigger mechanisms for revision is considered a special characteristic of the Uruguayan system. Studies of the Uruguayan system by other rice producing countries recognize this as a factor that encourages investment in the sector and that has enhanced the competitiveness of the Uruguayan system through its focus on the use of certified seed, quality at milling and response to the marketplace. Participants in the system, in their publications and interviews, also treat it as a positive factor. The close link between industry and growers seems to have facilitated innovation and the replacement of varieties as new ones become available. The nature of the "contract" or the "partnership" is evolving and the recent purchase by a Brazilian company of 50 percent of the Uruguayan milling capacity may change the dynamic.

At the level of the technical agenda, Round Table on Rice (Mesa de Arroz) brings together representatives from industry, research and academia in a forum for discussion of priorities and technical responses for the sector. Public records of their meetings suggest that the mechanism is consultative and not involved in the mainstream of decision-making.

The objectives and priorities of the rice programme in INIA show that INIA responds to market/industry demand. INIA's Rice Working Groups provide a formal mechanism to detect sector demand and discuss research priorities. The success of this effort can be seen in the fact that three INIA varieties account for 95 percent of production. The industry's concern with quality and markets has limited production to three INIA varieties, but INIA is carrying out research (with the private sector) on the development of Clearfield varieties and use of the Clearfield system. As Clearfield rice is not a GMO, there are no restrictions on exporting it to Europe. About 3000 ha in Uruguay were planted to Clearfield rice in 2009/10.

External environment: inflows from global knowledge

Uruguay is tied into many public and private-sector research networks, including FLAR, international agricultural research centres and activities with BASF.

FLAR was created by Latin American countries to fill a gap in cooperative international research on rice in Latin America, left by the decrease in rice research in the International Center for Tropical Agriculture (CIAT). However, CIAT still hosts FLAR and provides upstream collaboration in biotechnology and research strategy. INIA pays for FLAR membership (US$ 66 000/year) and participates in the Administrative (Steering) Committee together with ACA. INIA has invested in equipment that allows it to do controlled experiments on cold tolerance in cooperation with FLAR. The good balance between plant breeding and crop management innovations in Uruguay is evidence of a three-way flow of ideas among INIA, industry and FLAR. FLAR has strongly expressed the view that the present constraint to higher farm productivity is agronomic and not genetic. Uruguay has demonstrated the combined value of genetics and crop management. Uruguay does not seem to have suffered from a "failure of breeders and agronomists to develop strategy together" (Jennings 2007).

In links with the private sector, INIA is working with BASF in conducting research and developing varieties testing the Clearfield system, with a view to strategic use for chemical control of red rice.

Resources for research

The INIA rice research programme is based at Treinte y Tres but has staff attached also to INIA Tacuarembo and Las Brujas. The programme is staffed by seven PhD scientists, seven engineer-agronomists with MScs, one engineer-agronomist with a BSc and two agricultural engineers.

The rice research programme is supported by the INIA core budget and royalties from a consortium that has the license for INIA varieties.

The impact of rice research

INIA has just announced a public tender to develop a methodology to assess the impact of its research and to carry out the analysis. This will be a valuable part of INIA's strategic positioning at the time of a new administration. Some of the analysis in the current document is designed to put issues in an AIS framework.

In the meantime, INIA, IICA and PROCISUR (2009) attempted to explain increases in the economic surplus gained by producers adopting new technology (Table 5). After demonstrating the existence of a gain, researchers carried out a survey of adopters of particular innovations, the weight they put on that innovation and the importance they attributed to INIA's role in each technology.

Table 5. Attribution of INIA contributions to generation of rice technologies.

Technology	Attributed credit to INIA in generation of the technology (%)
Varietal change: El Paso 144	40
Varietal change: Olimar	100
Varietal change: Tacuari	60
Appropriate planting dates	75

Reduction of ploughing using glyphosate	35
Timely irrigation	70
Timely control of weeds	75
Appropriate fertilizer (management of nitrogen fertilizer)	75

The researchers also positive or neutral effects of INIA technologies and crop management practices on the environment and social goals such as equity.

This research highlights at least one important finding and one important corollary. The important finding recognizes the critical role of crop management research in support of varietal development. Without the accompanying research on planting dates, timely irrigation and control of weeds, the new varieties would not have achieved their potential. The important corollary is the importance of adequate public funding of research. INIA's breeding programme is partially funded by the royalties it receives for the use of its varieties, whereas the agronomic research that created much of the gain is classic public good research and non-appropriable. It underscores the importance of adequate public funding for INIA research and care in costing its contribution to research and the share of the royalties due to INIA if the variety is owned by partners.

Plant breeding and associated agronomic studies in rice: the influence of FLAR

The stylized facts regarding rice plant breeding and associated agronomic studies in Uruguay can be summarized as: 1) development of locally adapted varieties and associated packages; 2) development and release of hybrid rice using an INIA parent (association with RiceTec) and developing of varieties for the Clearfield system (in association with BASF); and 3) investment in associated crop management research.

Jennings (2007) described an alternating pattern between "green revolutions" and "agronomic revolutions," each of which increased productivity by the equivalent of 2 tonnes/ha. The current agronomic revolution (credited with bringing Uruguay's yields above 8 tonnes/ha) will call for a new genetic leap. He summarizes FLAR's efforts as follows:

> FLAR has combined two underappreciated traits – delayed leaf senescence (ageing), or "stay green", and huge panicles – while maintaining heavy tillering capacity. We expect the enhanced yield capacity of this new plant type will catalyze a second Green Revolution.

The rice plant-breeding system (PBS) seems to have struck the right balance among integration with the local value chain, participation in regional research and genetic and agronomic research.

Development and adoption of local varieties

INIA successfully created locally adapted varieties of rice that made the crop temporarily the primary agricultural export of the country when prices soared in 2008.

The stylized facts of the genetic improvement programme in 2007–2008 are summarized in Table 6.

Table 6. Rice genetic improvement programme, Uruguay, 2007–2008.

Activities	Description	Notes/outcomes
Purified lines given to seed sector	Long grain L5388, L5502	INIA Seed Unit
New experimental lines	Long grain L5287, L5578	Purified by INIA Seed Unit
New promising lines for evaluation with producers	L5502	Yield 6% greater than INIA Tacuari
Evaluation of short-grain lines for Asian market	C289	Purified by INIA Seed Unit
Cultivars evaluated	2 433	65% local, 35% through FLAR 61% long grain American quality; 24% long-grain tropical or indica; 9% short grain; 6% Clearfield
Selected for National Network of Evaluation of Rice Cultivars	12	Evaluation INIA-INASE (2008–2009)
Molecular markers to identify three principal genes offering resistance to *Pyricularia grisea*	Tested advanced breeding lines	Used MAS to backcross these genes into indica cultivars: El Paso 144 and INIA Olimar
Completed installation of INIA biotechnology lab at Treinte y Tres.	Apply molecular techniques and tissue culture	Decentralization of MAS from Las Brujas to other stations.
RiceTec/INIA agreement	Evaluation and use of INIA materials in hybrid combinations	Released first hybrid (Inov) with a progenitor from INIA In Mercosur region, 3 240 ha are being cultivated
Research on Clearfield System (Agreement BASF)	Evaluation of lines from local crosses and selections that are resistant to imidazolinone	2008–2009: Introduced new local Clearfield line in national evaluation which outperformed other introduced lines

INIA is mainly involved in conventional variety development. It has research agreements with RiceTec to test some of its breeding lines in hybrid combinations and commercial agreements to use successful parents in hybrid production. INIA is receiving royalties from one RiceTec hybrid and will soon receive royalties from a second one (Pedro Blanco, Head of Rice Programme, Personal communication, 2010).

Clearfield system: experience elsewhere and expectations

The Clearfield system is designed to address the problem of chemical control of red rice, a close weedy relative of rice that reduces yields and is costly to separate from quality rice at milling. It is present in Uruguay but is less of a problem than in Brazil, where important crop management practices are less strictly followed.

The Clearfield system, developed by BASF, is based on a mutation that confers resistance to the herbicide imidazolinone. Since it is based on a mutation of the rice plant's genes, it is not a GMO.

Experience in the US and research in other regions identify a number of issues with Clearfield rice (Rodenburg and Demont 2009):

- While it is easy to use, its efficiency is linked to careful management of irrigation and timing of application.
- In smallholder cultivation in sub-Saharan Africa it has proved difficult to create and maintain isolation zones to prevent gene flow. This is due to small, fragmented plots and also to the heterogeneity of developmental stages (and hence flowering) of the crop and weedy relatives.
- Out-crossing with conventional varieties tends to produce only late-maturing, large F_2 hybrid plants that can be prevented from going to seed. However, with the hybrid Clearfield varieties the dangers of outcrossing are more severe as the hybrids become more popular. Herbicide resistance is basically inevitable with the imidazolinone family of herbicides. With judicious use, crop rotation and tank-mixing, however, it can be delayed or even prevented.
- Herbicide resistant weeds can be generated by repeated use of a single class of herbicide and selection pressure will cause a shift in weed populations towards resistant biotypes. This is considered to be a greater source of herbicide resistant weeds than pollen-mediated gene flow.
- Plants appear more likely to develop imidazolinone resistance than glyphosate or glufosinate resistance.

- The previously claimed environmental benefits of herbicide resistant cultivars, based on the use of relatively benign post-emergence herbicides, is reduced by the fact that, in practice, other products still have to be used.

According to Rodenburg and Demont (2009) successful adoption of herbicide resistant cultivars requires:

- high level of farm management capacity to identify herbicide resistance in weeds and follow the "stewardship" requirements;
- substantial commercial market for the product;
- a strong private sector (agro-industry and input supply) that ensures an ability to eradicate weeds escaping the first chemical treatment;
- low seed cost to encourage purchase of certified seed each cropping season;
- protection of intellectual property (or the choice of "biological intellectual property rights protection in hybrids");
- binding agreements with agro-industries and the public sector to invest or build strategic partnerships;
- government capacity to carry out full biosafety assessments.

All of these conditions are present in the Uruguayan rice subsystem.

Rodenburg and Demont (2009) also quote Hareau *et al.* (2006) on the need for public–private partnerships in sub-Saharan Africa:

> A model for effective [public–private partnership] could consist of the private sector developing beneficial traits in major commercial crops, and the public sector providing a range of adapted germplasm into which these traits can be introduced (Delmer, 2005). Required support from government and non-governmental organizations would involve credit, training, and seed and herbicide supply systems, preferably with private sector participation (De Groote et al., 2008). Micro-credit or two-tiered price systems, where technology feeds will be charged as proportional to the scale of the farm, could alleviate some of the investment risks for small-scale farmers (Delmer, 2005).

The findings of Hareau *et al.* (2006) are noted here for inclusion in the cross-country comparison.

3.2 Cross-commodity comparison: maize, wheat, barley and soybean

Section 1 described an approach to analysing the role of the PBS in a systems context. Section 3.1 examined the case of the rice subsystem in some detail to show how the various components function to produce the desired goal: a dynamic rice export industry supported by forward-looking research in close contact with farmers and an integrated value chain. We now attempt to see if this level of detail needs to be replicated commodity by commodity for us to make a rapid appraisal of priority needs for plant breeding and crop management research.

Section 2 discussed the transformation of agriculture that has taken place in the past 15 years. The rice story is not just about a commodity chain but is also linked to the rice–pasture system and appropriate agronomic and crop management practices. A parallel story would be that of the soybean–cereals system. This has assumed a greater role in Uruguay following the rapid growth of transgenic soybean production, which called for rotation crops, particularly wheat and barley. The experience with maize, once an important commodity in domestic research, illustrates the way in which an external shock (transgenic maize) can change the system.

Section 3.2 looks at four important crops in Uruguay and the role that the national PBS plays.

The following stylized facts are drawn from the information presented in Table 7:

- Wheat production is undergoing a resurgence linked to the crop's complementarity to soybean in a rotation. Once a major crop, wheat regressed to the point where Uruguay was importing more than 30 percent of its requirements. In quantity terms its current export surplus is not large enough to affect global prices. However, Argentina and Brazil are likely to experience good harvests at the same time as Uruguay, which means that prices are likely to decline just when Uruguay wants to export. If wheat is to occupy a growing role in production and exports, key diseases (fusarium head blight and rust) will have to be controlled, yields increased and competitive export quality delivered.
- Maize research has been virtually discontinued in Uruguay with the exception of maintenance of some local criollo varieties for use by the family farming sector. The conversion some former pasture land to soybean cropping will increase the demand for feed.
- Barley fits as a rotation crop with soybean but the demand for barley is tightly linked to the demands of the malting industry.
- Soybean production is being driven by Argentinian investment. Argentinian farmers are purchasing or renting land and converting land that was formerly pasture to annual cropping. The industry is export-oriented with little value added since the crushing industry cannot compete with installed capacity in Argentina.

During the field visits undertaken for this study, it became clear that in order to understand the future capacity needs for the cultivar development and crop management, it is necessary to understand the linkages in rice-pasture evolution and soybean-wheat/barley complementarities instead of looking narrowly at a single commodity value chain.

Table 7. Basic economic, technical and institutional features of commodity chains for maize, wheat, barley and soybean in Uruguay.

	Maize	**Wheat**	**Barley**	**Soybean**
Area planted	85 000 ha	243 000 ha	138 000 ha	447 500 ha
Domestic consumption	Three types of maize: a) for grain, b) for silage, and c) “horticultural” (sweet corn). Animal feed dominated by imported transgenics. Small and medium family farms using criollo maize for domestic, poultry and silage. Uncertain quantity of "horticultural maize" is imported from Argentina.	Historically a major commodity for Uruguayan research when wheat was thought to have a comparative advantage. Country briefly in net import position in 1980s. Local demand generally satisfied by local production with potential for some export	Malting barley vertically integrated with malting industry.	Driven by demand for protein meals for feed industry. Small net imports of oil and meal.
Exports	Limited to local cross-border trade with neighbouring countries.	Small and variable export surplus historically easy to market. Brazilian market able to absorb small surpluses but production in Brazil and Argentina tends to rise concurrently with Uruguayan bumper crops with price consequences. Quality constrains potential markets in US, Europe	Brazilian breweries and export market can take growing production if malting quality.	As small global producer, Uruguay's rapid growth of soybean production easily absorbed when global production is weak. However, strength in US, Brazilian and Argentinian production in 2010 puts downward pressure on export prices. Soybean remains attractive relative to other crops.

Table 7. Basic economic, technical and institutional features of commodity chains for maize, wheat, barley and soybean in Uruguay.

	Maize	**Wheat**	**Barley**	**Soybean**
Technical	Hybrid and transgenic varieties present in all three types of maize. The local market for family farming trades off lower yield and lower cost s for on-farm self sufficiency for smaller-scale farmers.	Wheat grown in rotation with soybean. Continuous research battle against fusarium head blight and leaf rust. Preparing for Ug99 pandemic.	Grown in rotation with soybean. Research issue is quality for malting.	Rapid expansion of soybean driven by direct seeding with Roundup Ready soybean. Disproportionate growth of soybean requires expansion of rotation crops. Systems implications are more than a soybean concern.
Structure of sector	Major international seed companies supply transgenic, hybrid seed and market exports. Seed is almost totally transgenic hybrids. Niche market for small and medium farms consuming on farm.	Most wheat processed in 15 mills. Quality of Uruguayan wheat is good for all uses locally but not high in international export market.	Ambev controls largest part of industry (Malteria Uruguay, Malteria Oriental). Ambev varieties perform well in evaluation trials.	Major import and export companies bring seed, assist with inputs, and sell output in global markets. Within Mercosur, Uruguay's competitiveness is in its transport and market structure.
Policy issues	GM maize lines MON 811 and Bt11 transformed sector.	Expansion of wheat requires plant health and processing quality since local market is limited. Grupo Trigo designed to increase productivity and quality through increased use of certified seed.	Raise the level of certified seed used.	Argentinian investment (capital flight) is driving expansion. Transformation of crop sector is more than a commodity production problem. Argentinian economies of scale limit opportunity for crushing industry in Uruguay. GNBio approved trials of

Table 7. Basic economic, technical and institutional features of commodity chains for maize, wheat, barley and soybean in Uruguay.

	Maize	**Wheat**	**Barley**	**Soybean**
				new GM varieties in 2009.
Special programmes	Research left to external private sector and imported seed.	Grupo Trigo: a strategic partnership between INIA and seven large cooperatives to raise quality of Uruguayan wheat.	Research in INIA and university as well by malting companies.	Research left to external private sector and imported seed.
Seed sector strategy (Alfaro *et al.* 2009)	Hybrid: 31 cultivars Objective: Yield increase Economic impact: Cost reduction per unit of output GM (Mon 810): 54 cultivars GM (Bt11): 7 cultivars Objective: Simplification of tasks, higher yield Economic impact: Cost reduction per unit of output and per hectare	INIA (29%): 8 varieties Others (54%): 10 varieties Objective: Disease resistance, quality. Minimal increase in yield Economic impact: No major economic impacts	INIA (50%) Objective: Disease resistance, quality. Minimal increase in yield Economic impact: Access to markets (malting industry)	GM: 32 cultivars Objective: Simplification of tasks; acceleration of cultivation Economic impact: Cost reduction per unit of output and per hectare

The seed sector for maize, wheat, barley and soybean in Uruguay

The seed sectors of the four commodities are quite different from each other (Table 8). The coverage of certified seed differs across commodities, as does the degree of integration of the chains. This argues in favour of subsector specific policies and institutional arrangements.

Table 8. Status of the seed sector for maize, wheat, barley and soybean in Uruguay, 2008.

Seed sector	Maize	Wheat	Barley	Soybean
Seed imports	Net deficit in maize seed: US$12.2 million. No sweet corn seed produced locally. Top two importers of hybrid seed account for 35% of total.	Net deficit in wheat seed: US $5.8 million. All major companies (Nidera, Agar-Cross [DuPont], Agro-Negocios del Plata) involved in market.	In 2009, INASE reports 70 500 kg of seed imported, 80% “Goldie”.	Don Mario (Argentina) controls 40% of market.
Seed exports	Small export to Europe: production in counter-season (US$140 000)	Negligible exports or not identifiable in INASE statistics	Negligible exports of seed or not identifiable in INASE statistics	None
Use of certified seed	80–90%	60%	35%	100%
Observations	International Plant Breeders (IPB) is the only domestic company producing hybrids. (Single hybrid modified IPB 880 MG). Informal networks exist for exchange of criollo seeds.	Some “Baguette” varieties (Nidera, Uruguay) contain Lr37 gene for resistance to leaf rust. Not all “Baguette” varieties do.	Malting quality and disease resistance remain critical research issues.	Technology is imported. Argentinian farmers bring what they know.

3.3 Organizational structure and institutional arrangements: different problems require different arrangements

As noted in Section 1, this study looks at the role that plant breeding plays in the national agricultural innovation system. The innovation literature usually differentiates itself from previous approaches by reference to one or more of the following themes: 1) equal attention to the demand and supply sides; 2) multiple sources of knowledge; 3) a broader range of goals beyond productivity; 4) learning and adaptive management; and 5) a wider range of actors and agendas to be negotiated. In practice, much of the literature ends up dealing with particular value chains.

At the start of this study, it was the author's intention to look at three commodity sectors, maize, rice and vegetables, that could be compared with experiences in other case-study countries. Following the field visit, it became clear that there was more to be learned by looking across maize, rice and other commodity systems in Uruguay.

The organizational structure of agricultural research in Uruguay at the macro level is described in Section 2. This showed that INIA is organized along commodity lines; the university is organized in faculties by disciplinary lines; and there are a few institutional arrangements that bring disciplinary skills of UdelaR into specific commodity or thematic research.

Different challenges require different institutional arrangements. Here we put forward a number of hypotheses (stylized facts) about the Uruguayan system that have some implications for research.

- INIA and UdelaR each work in its area of comparative advantage: development oriented research for INIA and generation of discipline-based knowledge for UdelaR.
- It is easier to coordinate centralized and decentralized research in a small country than in a large country.
- It should be possible to coordinate resources around tasks, commodities, target groups, market objectives or regions without having to change organizational structure.
- The mechanisms for collaboration (e.g. competitive funds, research contracts) have been working, but there is a need for strengthened mechanisms of consultation or strategic planning around areas of collaboration.
- Uruguay has been able to manage the coexistence of various institutional arrangements in a way that serves a variety of R&D objectives. This is one element of "capacity" that needs to be recognized or strengthened where necessary.

Table 9. Linking institutional arrangements to objectives for the rice, maize, wheat, barley and soybean sectors in Uruguay

	Rice	Maize	Wheat	Barley	Soybean
Value chain	Integrated			Integrated	
Market	Exports linked to high quality	Domestic feed	Domestic market	Domestic with	Export by major

Table 9. Linking institutional arrangements to objectives for the rice, maize, wheat, barley and soybean sectors in Uruguay

	Rice	Maize	Wheat	Barley	Soybean
	and non-GMO Diversifying markets away from Mercosur	industry Family farms for silage, poultry, hogs	satisfied Quality needed to export growing surpluses	export of malt Export market could be elastic	international companies. Uruguay small global producer Vulnerable to prices
Policy	Coexistence Management of non-GMO in rice	Transgenic IPR and royalties	Relates to growth of soybean	Relates to growth of soybean	Transgenic IPR and royalties
Regulatory		INASE monitors refuges			
Industry structure	Highly concentrated	International seed market	15 mills	Concentrated	Limited processing
Mechanisms	ACA-GMA negotiation	Market	Grupo Trigo		
INIA special research	Quality for export Non-GMO Clearfield system	Niche for family farms No other research	Quality needed for export Resistance to disease (rust, FHB)	Quality for export, resistance to disease	Soybean system and rotation with cereal will be a growing issue
Seed system†	Varieties determined by industry, which also produces a large part of the seed	100% transgenic Regional and international seed; IPB only domestic hybrid grower	High use of farmer seed; Grupo Trigo seeks to raise use of certified seed	Growth of market. Attempt to increase certified seed needed	100% transgenic Imported seed

ACA – Rice Growers' Association; FHB – fusarium head blight; GMA – Rice Millers' Union; IPB International Plant Breeders; IPR – intellectual property rights.
† See also Table 7 derived from Alfaro *et al.* (2009).

Not every commodity faces the same market, industry structure and regulatory problems. It is, therefore necessary to evolve the right tools for the right problem. Table 9 shows some details that link markets, industrial structure and objectives for the research and seed systems. From this information, we make the following observations about the different arrangements operating in the various commodities:

- An integrated export value chain operates in rice. The industry chooses varieties for their milling and export needs. The contracts and incentives it provides for use of certified seed has ensured high quality. Research has delivered varieties and cultural practices that achieve high yields by international standards without use of GMOs. The industry is highly concentrated (Saman/Camil accounts for 50 percent of the milling.). The integrated value chain, with the negotiated arrangements between millers and rice growers, has been accepted by all parties. Policy is strongly linked to diversification of export markets outside of Mercosur.

- Barley production is linked to the malting industry. The industry is concentrated and potentially has an elastic export market; Malterias Uruguay S.A, and Malteria Oriental (through its Argentinian parent) are both subsidiaries of Ambev, which is owned by American giant Anheuser-Busch. Key issues are quality and resistance to diseases. INIA and UdelaR research into sources of resistance will be critical. Barley's complementarity to soybean gives it growth prospects if quality can be maintained and disease overcome.
- Wheat has recently experienced rapid growth, linked to the increase in soybean production. The varieties that are grown are of adequate quality for the domestic market but the growing export surplus must compete in difficult markets both on price and quality terms. The value chain is not integrated. The Grupo Trigo, formed by INIA and seven large cooperatives, is an arrangement on the supply side to raise quality and productivity to compete in regional and global markets.
- Production of maize for the domestic feed industry is fairly stable, with some increase in demand associated with the conversion of some cattle grazing areas to cropland. The market is dominated by transgenic hybrids; only one domestic company, International Plant Breeders (IPB) produces domestic hybrids. INIA does a minimal amount of research on varieties for family farms that want to produce their own silage. This is a "niche" market.
- Soybean has experienced rapid growth fed by Argentinian investment and strong demand from Asia. Uruguay remains a small producer in global markets. Prices fluctuate with trends in major producing countries and Uruguay is vulnerable to decisions made in those countries. The varieties planted are imported and the product is exported without processing. Sustainability requires soybean–cereal or other rotation system. It is not clear where in the current INIA programme this is being addressed but it is not a soybean problem alone.

The system has been able to adapt mechanisms to manage collaboration among the partners for research solutions to market problems within particular commodity subsectors. These solutions have been a balanced package of plant breeding and agronomic practices at the commodity level.

Managing transformation

The soybean case highlights a challenge for INIA but also for higher-level decision-makers: the need to manage a major transformation in the Uruguayan agricultural sector. Annual crops are advancing on grazing lands. Their value as exports has been a driving force in export growth. These changes present new challenges for research.

4. Lessons for plant breeding

The Uruguayan experience brings out several lessons that small countries can learn from:

- An export niche, such as Uruguay's position in conventionally bred rice, can be captured if there is a good breeding system backed up by agronomic expertise.
- Uruguay's experience illustrates Peter Jennings' (2007) argument that after the first semi-dwarf varieties, gains have been due to conversion to irrigation and fine tuning of planting dates, irrigation and applications of chemicals and not to further genetic improvements in productivity.
- A strong link to the market and the industry's ability to influence varietal choice by farmers has had three beneficial effects: 1) milling and processing quality meet market requirements; 2) rice growers and seed producers have a stable market environment; and 3) farmers almost exclusively use certified seed, much of it produced and marketed at low margins to growers by the industry.
- Public–private partnership needs to be close. Small countries have little comparative advantage in upstream research but can be effective users of international knowledge once it is adapted to local conditions.
- The strength of the PBS lies in its ability to take on new challenges that bring plant breeding and crop management together (e.g. the rice–pasture system and the soybean–wheat/barley rotation). The links in integrated value chains, such as those for rice and barley, need to be understood and arranged on a commodity-by-commodity basis.

With respect to support for research, the 0.4 percent tax on sales of agricultural products that goes to support INIA has been an important part of the strength of the system. Ten percent of the fund is allocated to competitive grants for collaboration with the UdelaR and other actors in the system. These funds have enabled INIA to adapt its efforts to new opportunities and challenges.

With respect to the capacity for plant breeding, INIA has not attempted to compete with the private sector in producing transgenic maize and soybean seeds, yet has satisfied the domestic market for the former and a growing export market for the latter through imports (many from established companies in Argentina). On the other hand, INIA has been very good at supporting evaluation, selection and plant breeding for wheat, barley and other crops where local system issues, such as disease, are not adequately addressed by outside seed suppliers.

The FPTA has brought some collaboration with UdelaR. The number of FTE researchers in UdelaR is growing relative to INIA, indicating the need for a strategic partnership between them, but one that recognizes the university's need to generate knowledge that can be used by the more cultivar-development-oriented researchers at INIA. The emergence of a strong innovation system requires ever-increasing collaboration among components of the system. New support is coming through the GMI and programmes such as Innovagro Fund operated by ANII.

In conclusion, INIA has played a strategic role in helping Uruguay recover from the 1998–2003 financial crises, capturing the opportunity created by outside investors and new commodities, and managing a transition from livestock to cropping in new areas. The capacity to monitor the environmental and social impacts of this transformation of the sector exists because of a reliable funding mechanism which by design strengthens a historically weak relationship with the UdelaR.

Conclusion

This report puts forward several potential lessons for organization and functioning of plant breeding and seed systems. First, a small research system can still play a strategic role through plant breeding and associated crop management. In the Uruguayan case this is shown by an ability to devolve some activities to the private sector and to concentrate capacity in areas where it can produce technologies suited to the local situation. The rice–pasture system is a clear case which is productive, economic and environmentally acceptable. Second, close integration with the private sector ensures relevance and user funding for research, although this may result in reluctance to change varieties rapidly. Third, research has to be looking ahead to future challenges. In the case of rice, INIA's research on hybrid rice (Clearfield system) with a view to having a non-GM tool against red rice is far-sighted. Finally, a small country may have an advantage administratively in monitoring biosafety, protection of breeders' rights and increasing the use of certified seed. Investment in reliable institutions is an essential part of a functional plant breeding system.

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Useful websites

Asociación Cultivadores de Arroz: http://www.aca.com.uy

Cámara Uruguaya de Semillas: http://www.cus.org.uy

Facultad de Agronomia, Universidad de la República (UdelaR): http://www.fagro.edu.uy/

Federación LatinoAmericana de Associaciones de Semillas: http://www.felas.org/

Instituto Nacional de Semillas, Uruguay: http://www.inase.org.uy/

International Seed Federation: http://www.worldseed.org/isf/home.html

Instituto Nacional de Investigaciónes Agropecuários: http://www.inia.org.uy/online/site/

Ministerio de Ganaderia, Agricultura y Pesca: http://www.mgap.gub.uy/portal/hgxpp001.aspx

Asociación Civil Uruguaya para la Protección de los Obtentores Vegetales: http://www.urupov.org.uy/

Annexes

These annexes are included as a tool for future researchers. Annex 1 presents a generic framework for diagnosing agricultural innovation systems. Annex 2 lists significant events in the evolution of the Uruguayan agricultural innovation system. The events were compiled from websites of organizations or were included because an author of a study has cited the event as evidence or illustration of a point. By describing, dating and characterizing events by commodity, nature (e.g. policy, economic, technical, scientific or institutional) we can relate previously unrelated events through searching and filtering to provide an evolutionary or relational perspective. Annex 3 summarizes information on the programmes and units of INIA. Annex 4 documents the international affiliations of the domestic seed and processing industry to give insight into the structure and behaviour of the units.

Annex 1. A generic national agricultural innovation system1

Figure 1 depicts a generic agricultural innovation system (AIS) at the national level.

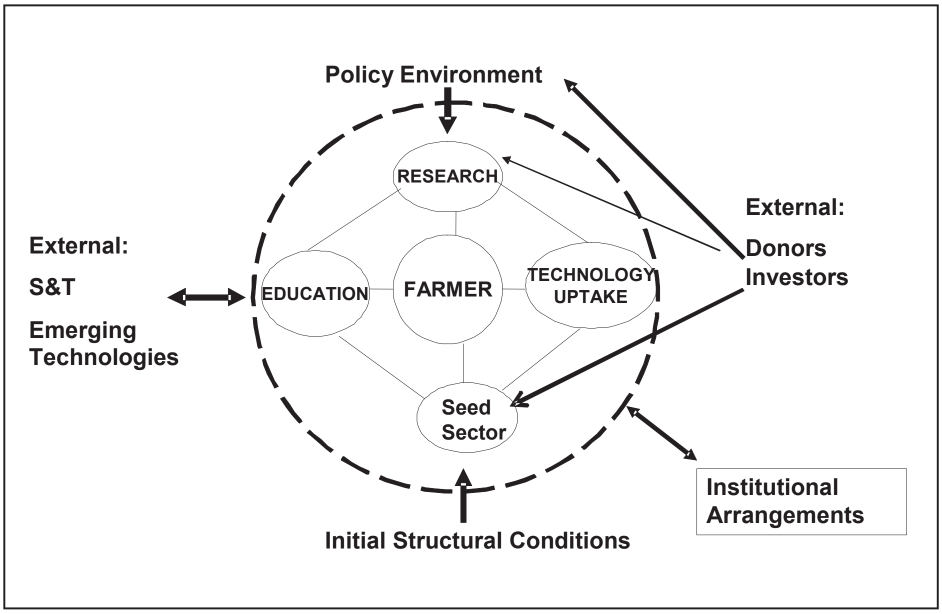

Figure 1. Evolution of key components and relationships in an agricultural innovation system.

Source: Adapted from Elliott (2008) the presentation in the Addis Ababa conference is the most recent reference

A system is defined as a set of parts coordinated to achieve a common objective. It is defined by its objectives, components, resources, means of coordination and environment. Treating the Plant Breeding System as part of an innovation system, we can specify the elements of the system:

Objective: to generate and ensure the adoption and use of plant-breeding outputs to improve productivity, sustainability and welfare of producers.

Components: Farmers, research organizations, educational institutions, technology transfer agents (extension, NGOs, crop insurance, credit suppliers), the formal and informal seed sectors, institutions and organizations addressing the objective, and the environment (policy, exogenous science and technology,

[1] Adapted from Elliott (2008).

global and regional institutions and funding agencies including government).

Resources: human and financial resources and how they are allocated are a measure of the functionality of the system

Coordination: coordination of policy and the various actors is endogenous and varies by commodity.

The AIS framework can be applied at various levels of decision-making: integrated subsector programmes and value chains; organizations and institutional arrangements among them for collaboration; geographical units of analysis and national level policy goals. The efficacy of flows of ideas, resources and commitment across the levels (vertically) and coordination among organizations horizontally are strengthened by a shared view of the system's coherence.

The following section describes the Uruguayan AIS as a working model of stylized facts and relationships that are subject to correction or fine-tuning as necessary to derive useful insights.

The Uruguayan plant breeding system as part of the Uruguayan national agricultural innovation system

A national agricultural innovation system (NAIS) only becomes a reality when policies, incentives, investment and coordination of individual efforts seek to achieve a common purpose. Presumably, for the Uruguayan NAIS this would relate to 1) maintaining agriculture's contribution to economic growth through sustainable exploitation of its comparative advantage based on climate, natural resources and educated farmers; and 2) enhancing Uruguay's interests in Mercosur and global markets.

The national plant breeding system (PBS) is a subsystem of the NAIS. It is also as a strategic instrument for attaining national goals that would be otherwise unattainable because of the limitations of size and market influence.

Objectives: The objective of the Uruguayan PBS might logically include some or all of the following specific objectives:

- Support the public and private sectors in the rapid adaptation of agricultural technology to changing scientific, market and institutional conditions
- Based on technology foresight, initiate research that will anticipate future changes so that the research lags will be shortened
- Participate in international and regional networks that ensure access to knowledge, science and technology of potential benefit to Uruguay

- Establish links with policy-makers, private-sector agribusiness, NGOs and civil society organizations and maintain mechanisms that ensure responsiveness to market, farmer and processor needs.

Components: The core of the AIS is composed of: 1) the research system; 2) the agricultural education system; 3) the extension or technology uptake system (collectively sometimes called the knowledge triangle); and, in our definition, the PBS. These four components place the farmer, the fifth component, at the centre of the system.

The following are the stylized facts about these components that have some analytical importance.

Farmers

- The agricultural population accounts for 8.8 percent of the total population of Uruguay, but agricultural employment accounts for only 4.4 percent of total employment.
- Agricultural value added accounts for 11 percent of GDP (averaged over 2003–3005), which means that it is an integrated part of the economy.
- While some family farms are small and use little high technology, there are few “poor” farmers in Uruguay in the usual definition of the term.
- In Uruguay, commodity associations of producers are important and powerful components of value chains, as in many developed countries.

Research system: INIA and UdelaR

- Total agricultural R&D spending rebounded rapidly after the 1999–2003 economic crisis. In 2006 it was the equivalent of US$60 million (in 2005 PPP dollars).
- INIA and the UdelaR are the largest R&D agencies, accounting between them for more than three-quarters of the country’s research capacity.
- Capacity in both organizations has been growing, with the UdelaR growing as a share in FTE.
- In plant breeding research INIA and UdelaR have different roles:
    - INIA does PBR *per se* while much of the university’s PBR is of a didactic nature or contracted as a scientific evaluation or input to others’ development programmes.
    - Traditionally the UdelaR has received very few core resources for research, with the result that individual scientists have operated at small scale and often under contracts from INIA.

- INIA has some research agreements with international centres and with private-sector companies. It participates in FLAR, a Latin American rice research programme that took over plant breeding when the international centres were not meeting the research needs of temperate companies.

Technology uptake

The activities that are commonly undertaken by an extension system in many developing countries are managed through a sophisticated network of organizations and partnerships in Uruguay:

- Early warning information on the potential emergence of disease or pests is distributed on websites by commodity groups and sponsored by INIA and input suppliers.
- Field days sponsored by INIA and INASE give farmers the opportunity to see the performance of varieties undergoing their 3-year testing prior to release.
- Special field days by commodity research programmes are a regular part of INIA's offerings.

The seed sector

The seed sector is well organized and features the following associations:

- Uruguayan Seed Chamber (CUS): 32 major seed companies engaged in agricultural inputs and marketing Uruguayan products. Changes in the structure of the seed sector have important implications for future research strategy.
- National Association of Seed Producers (Anaprose): a syndicate of 17 important companies that produce, process, market, export and import seeds.
- Rice Growers' Association (ACA): a powerful union of rice growers that negotiates with the millers and exporters.
- The union of the plant breeding sector (*sensu stricto*) and the plant breeding system/seed system (PBS/SS) can be considered as a subsystem of the higher order innovation system but the seed system is first discriminated as a separate system.

Policy environment

- Policy ensures management of the coexistence of transgenic crops and GMO-free rice. Uruguay gained a windfall when US exports of rice to Europe and some Middle-Eastern countries were stopped due to GMO "contamination".

- Uruguay is open to foreign investment in farming and processing, with large capital investments coming from Argentina and Brazil.
- Change in the structure of production and management have a number have encouraged: 1) exponential growth of transgenic soybean and changes in cropping systems (soybean–wheat/barley); 2) growth of rice production, which now exceeds meat in export value, leading to expansion of the rice–pasture system and imports of pasture and forage seed; and 3) domination of maize cultivation by transgenics and closing of domestic maize research.
- There is increased need for technology foresight to ensure that structural changes are adequately supported by the research system.

Resources and coordination of the system

The system has been adequately funded through earmarked taxes in support of INIA, competitive funding that brings UdelaR into project-level collaboration and the creation of new funds for "innovation more broadly in the economy (e.g. Innovagro). The creation of a National Agency for Research and Innovation (ANII) is designed to build capacity, create incentives for scientists and enterprises in priority areas and facilitate collaboration. The strategy for an "Innovative Uruguay" shows a conscious interest in improving competitiveness through innovation.

The means of coordination of the PBS/SS have reached a relatively high degree of sophistication characterized by: 1) organization of components in representative organizations that participate in policy-making at various levels; 2) financing mechanisms for research that give stakeholders a powerful voice in the direction of the system; and 3) agreements between industry, seed producers and growers that provide stability to the system at the start of the crop year and provisions for adjustment in light of developments during the season.

As discussed in the case of rice, the integration of the value chain is a key characteristic of the system. Its impact on the competitiveness of the Uruguayan rice industry (positive), stability for farmers (positive), meeting needs of industry (strong) and support from the research system (strong) are widely voiced. Such structures are often insulated from pressures for innovation and one of the issues to examine is whether technology foresight and public-sector investment is anticipating future changes coming from the external environment.

The environment for the PBS/SS

Referring back to Figure 1, the PBS/SS is found within an environment composed of four influences:

6. a policy environment (both domestic and international)
7. private investors and donors (multilateral lending agencies in the case of Uruguay)

8. external science and technology opportunities and challenges
9. initial structural conditions (including membership in regional blocs and international agreements).

These forces act on Uruguay through a number of institutional arrangements represented by the circle of dashes in Figure 1.

Most of the stylized facts that have analytical importance have been included under the policy environment. However, it is also useful to consider the importance of Mercosur and how Uruguay can exploit its hosting of the organization.

Annex 2. Key events in the evolution of agricultural innovation in Uruguay, 1869–2010.

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
1869	First references to rice trials	Agronomic	Rice	Private		Benchmark date
1911	Creation of six agronomic stations following German and US models	Institutional	All	Pre-INIA		Stations created to promote training, research (genetic improvement) and diffusion of scientific results. Search for best local wheat varieties for adaptation to local conditions. By 1918 had released first wheat pedigree lines from *criollo* lines resulting from natural selection of seed brought by immigrants.
1919	Foundation of National Crop Science and Seed Institute	Institutional	All	Public		A pioneer agricultural experiment station in South America. Focus on scientific selection of wheat, oats, barley, flax and legumes.
1919	Santa Rosa de Cuareim (now Bella Union) first rice farm in Paysandu	Production	Rice	Private		Benchmark date
1924	New pedigreed wheat 'Artigas' diffused	Plant breeding	Wheat	Pre-INIA		Successful until attack of new streak rust pathogen in 1929. Replacement varieties became available by 1933
1927	Rice farmers establish in Eastern Zone (Laguna Merin)	Production	Rice	private		Beginning of concrete data on rice
1934	La Estanzuela began research on industrial and forage crops	Plant breeding	All	Pre-INIA	Brazil	Created a variety 'Estanzuela 284' from introductions of ryegrass from Brazil

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
1935	4 735 ha planted (production 14 965 tonnes)	Production	Rice	Private		Satisfied internal consumption with 2 300 tonnes exported to neighbouring markets
1940	5 000 ha planted	Production	Rice	Private		5 000 ha with yield of 3 400 kg/ha
1940	Passing of the Rice Law	Legal	Rice	Public		
1947	Producers create Rice Growers' Association (ACA)	Institutional	Rice	Private		Formal organization of rice growers. Preseason negotiations with the Rice Millers' Union after 1950
1950	Creation of Rice Millers' Union (GMA)	Institutional	Rice	Private	Public	Price of rice begins to be fixed by the government taking into account the cost of production
1959	Executive stops price fixing in rice	Policy, institutional	Rice	Public	Private	Price of rice begins to be fixed by agreement between ACA and the GMA in consideration of the costs of production, the internal price and export price and the proportion of rice to each market
1961	Creation of the Alberto Boerger Agricultural Research Center (CIAAB)	Policy, institutional	Crop and livestock	Pre-INIA		Reorganization of research in light of livestock as taking precedence in agriculture. Agricultural potential of Green Revolution starting to be noticed. CIAAB take on cattle, pastures and forage crops
1962	IICA and government create Center for Research and Training for the Temperate Zone located at La Estanzuela	Institutional	Research	Pre-INIA	IICA	Regional cooperation on temperate zone
1962	The Bank of the Republic approves a financing	Policy	Rice	Public	Private	Financing formula for rice cultivation gives a vigorous

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
	formula for rice cultivation					impulse to the crop
1965	Consolidation of CIAAB 1965–69	Institutional	Research	Pre-INIA		Broadening of CIAAB mandate: systems, soils, livestock systems, production certified seed, extension
1968	Executive declares cultivation and industrialization of rice to be of national interest	Policy, institutional	Rice	Public	Private	Creation of Honorary Commission for Rice Promotion, a mixed public–private commission
1969	Creation of the Experiment Station of the East (EEE-CIAAB)	Institutional	Rice	Public		EEE-CIAAB established. Rice a major commodity
1970	Regionalization of CIAAB 1970–1989.	Institutional	all			Expanded experimental activities in production systems relevant to each region.
1970	1970–1972 CIAAB annexed stations of Ministry of Livestock and Agriculture, created stations in Tacuarembó and Treinte y Tres	Institutional	Research	Pre-INIA		Long-term research, genetic improvement in crops and livestock and research on systems
1973	Sectoral Commission for Rice under Planning and Budget	Institutional	Rice	Public		Restructuring of the Honorary Commission for Rice Promotion as Sectoral Commission for Rice under Secretariat of Planning and Budget.
1973	Significant increase in yields due to introduction of new variety, 'Bluebell'	Production	Rice	Private	Public	Massive introduction of 'Bluebell', long-grain American rice, led to significant increase in yields 1973 and following years

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
1980	Agreement for the first time a reintegration of rice exports in the form of devolution of taxes	Policy	Rice	Public		Devolution of taxes maintained thereafter
1980	Technical cooperation agreement between Ministry of Agriculture and Private Rice Sector	Institutional	Rice	Public	Private	Ministry of Livestock, Agriculture and Fisheries (represented by CIAAB through experiment stations in the East (Treinta y Tres) and North (Tacuarembó) created and transferred technology for 10 years with cooperation of private rice sector up to the creation of INIA
1980	Decade of 1980s	Institutional		Pre-INIA		Successive stages of 1) genetic improvement, 2) management of crops and resources and 3) systems of production with regional networks laid basis for INIA
1981	Rice marketed through Protocol for Commercial Expansion (PEC) with Brazil	Production, legal	Rice	Private	Public	38 500 tonnes exported to Brazil
1986	'El Paso 144'	Plant breeding	Rice	Pre-INIA		Indica long-grain rice of American quality introduced
1986	Expansion of marketing under PEC	Policy, legal	Rice	Private		Authorization for market passes 200 000 tonnes
1987	Ley Forestal passed	Policy	Agroforestry	Gov		Create industrial poles in several regions based on plantation of rapid growing eucalyptus and pine. INIA work on genetic improvement of species, certification of seeds,

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
						propagation and release of species and management practices
1988	The State invests in important infrastructure with financial support from IDB	Infrastructure	Rice	Public		Road and rural electrification undertaken by State at the insistence of the private rice sector
1989	Creation of CUS	Institutional	All	Private		Association of 32 key enterprises and public agencies involved in regulation, production and marketing of seed
1989	Law creating INIA	Institutional		Gov	ISNAR	Create public non-statal enterprise with close links to policy through the Ministry of Livestock, Agriculture and Fisheries but based on principles of 1) participation of producers, 2) budgetary autonomy, 3) administrative flexibility and 4) decentralization
1990	Begin replacing 'Bluebell' rice (US) with 'El Paso 144' in association with industry and growers	Plant breeding, institutional	Rice	Public, domestic	INIA, ACA, GMU	Begin domestication of rice breeding and sector development. INIA 'El Paso 144' 10% of area planted
1990	Under PEC (protocol XV) rice exports to Brazil unlimited	Policy, legal	Rice	Public		Unlimited rice exports permitted under PEC
1991	INIA created Areas and Research Programmes	Institutional	All	Public, domestic	Public	Centres with regional mandate as well as national programme. Pasture cultivars released for different areas
1991	Treaty of Asuncion (Mercosur)	Policy, legal	Rice	Public		Law 16.196 of 22/8/91 created Mercosur

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
1992	Release of onion variety 'INIA Casera'	Plant breeding, agronomic	Horticulture	Public, domestic		Longer conservation, reduced use of chemicals
1992	Release of 'INIA Tacuari'	Plant breeding	Rice	Public Domestic		New INIA variety released. Benchmark date for use
1993	New varieties of sweet potato, strawberries	Plant breeding	Horticulture	Public, domestic		Cooperatives participate in testing varieties
1993	Regional Rice Meeting, LATU, Montevideo	Institutional	Rice	Public	Private	Regional meeting of rice actors held in Montevideo and organized by LATU – created in 1965 as public–private analytical laboratory later named Technological Laboratory of Uruguay
1994	Uruguay joins UPOV	Policy	All	Gov		Public recognition of plant breeders' rights; URUPOV as private association of owners of new varieties is UPOV member
1994	URUPOV created	Institutional	All		Private	Works to improve use of improved seed and planting material and eliminate seed of unknown origin from market. INASE resolution of 2005 facilitates collection of a *valor tecnológico* (end point royalty) on behalf of registered breeders by requiring farmers to identify all retained seed and its origin
1994	Georeferencing all citrus hills in country for traceability of product	Information, research support	Fruit	Public		Important capacity to support citrus and eventually other products where traceability is required
1995	Release of first variety of malting barley,	Plant breeding	Barley	INIA		Substitution of domestic varieties for imports. Start of

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
	'Estanzuela Quebrach'					integrated industry–grower–research system in barley
1995	Potato variety 'INIA Ipora' reduces imports of potato seed	Plant breeding	Horticulture	INIA		Benchmark start of substitution
1995	Government formally endorsed use of biotechnology	Policy, biotechnology	Policy	Gov		Create conditions for expansion of GMO varieties in Uruguay
1996	Technology for intensive meat production from sheep	Livestock systems	Meat, dairy, wool	INIA		Intensification, quality
1997	Soybean event 40-3-2 approved	Policy	Soybean	Gov		The event was approved in 1997 but soybean growth began with economic recovery in 2001 due to favourable conditions: available land, efficient technicians and companies, and stable business climate
1997	Creation of INASE by Law No. 16811	Institutional	All		Gov	The breeding, production, distribution and marketing of seeds and phytogenetic creations, both within the country and abroad, are hereby declared to be in the national interest. Public non-statal institute to promote and contribute to development of seed activity encouraging the use and production of quality seed
1997	50th Anniversary of ACA	Institutional	Rice	Private		Benchmark date
1997	Wheat variety 'INIA Tijereta' released	Plant breeding	Wheat	INIA		Benchmark year

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
1998	Fine Wool Program launched	Animal breeding	Livestock	INIA		Introduced 460 rams and 6000 doses of semen
1998	Genetic improvement of beef cattle	Animal breeding	Livestock	INIA		Enhanced efforts on quality for meat
1999	Use of satellite information.	Information, research support	All	INIA		Better control of disease in fruit and facilitates control of impact on environment
1999	Soybean event 40-3-2 approved	Regulatory, biotechnology	Soybean, policy	GOU		First use of GMO in Uruguay; Monsanto Roundup Ready
2000	First improved variety of eucalyptus produced and certified in Uruguay	Plant breeding	Agroforestry	INIA		Benchmark for agroforestry improvement
2001	Release of 'INIA Araza' strawberry with better flavour. New clones of 'Tannat' grape.	Plant breeding	Horticulture	INIA		Benchmark to monitor future use
2002	Release new variety of rice, 'INIA Olimar'	Plant breeding	Rice	INIA		Benchmark date to monitor use of variety
2003	Development of decision-support system for management of eucalyptus plantations	Research support	Agroforestry	INIA		Benchmark for agroforestry improvement
2003	Maize Event MON 810 approved	Policy, regulatory, biotechnology	Maize	Gov		Benchmark date for conversion to transgenic crops; Biosafety determination; Monsanto insect resistant maize; beginning of shift to almost 95% transgenic
2003	Creation of the Fund for Financing and Reconversion of Rice Activity (FFRAA)	Policy, financial	Rice	Public		Indicates strategic importance of rice sector to Uruguay

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
2003	Soybean area starts to rise from 77 000 ha	Policy	Soybean	Public		Influx of Argentinian farmers and investors
2004	Maize Event Bt 11 approved	Policy, regulatory, biotechnology	Maize	Gov		Benchmark date for conversion to transgenic crops; Biosafety determination
2004	Genetic improvement of wheat	Plant breeding	Wheat	Public		Wheat improvement aimed at yield and resistance to stem rust on INIA varieties but releases by others risk introducing new more virulent races
2005	INASE resolution 12/2005 requires farmers retaining seed for own use to clearly identify it with a prescribed label.	Policy	All	Public	INASE	The requirement that retained seed be identified facilitates collection of royalties
2005	Installed Council for Wages of Rice Workers	Policy, institutional	All	Private		Indicates increasing formalization of rice sector
2005	Introduction of environmental sustainability into research programmes	Sustainable systems	All	INIA		Research strategy and criteria
2005	Study of quality and botanical origin of honey in northeast of country	Strategic research	Family agriculture	INIA		Research of disciplinary or analytical nature that contributes to applied research
2005	Creation of Ministerial Cabinet for Innovation (GMI)	Institutional	Inter-ministerial	Public		Composed of Ministries of: 1) Education and Culture, 2) Economy and Finance, 3) Industry, Energy and Mining, 4) Livestock, Agriculture and Fisheries, and the Director of the Office of Planning and Budgeting

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
2005	Agreement signed between UDELAR and ACA for realization of projects	Institutional	Rice	Private	Public	University becoming more active in research for development
2005	Creation of Confederation of Latin American Rice Entities (CELARROZ)	Institutional	Rice	Private		Indicates strategic importance of rice sector
2005	Development of Strategic Plan 2006–2010	Policy, institutional	Rice	INIA		Recognition of the "tridimensionality" of agriculture: economic, social, and environmental. Redesign of programmes, units and management structure
2005	Rice lines LLRICE06 and LLRICE62 under research	Biotechnology	Rice	INIA		Genetically engineered resistance to glufonsinate but acceptance by growers and industry doubted due to potential impact on export markets
2005	An imidazolinone-resistant rice cultivar registered and commercially released under the name 'Puita INTA-CL'	Plant breeding	Rice	Public	INTA Argentina	In 2009 'Puita INTA-CL' was largest imported rice cultivar (418 404 kg) followed by Avaxi CL (66 532 Kg). Imported by BASF (Uruguay)
2006	Strategic Plan 2006–2010	Policy, institutional	All	INIA		
2006	INIA and National Commission for Rural Development agreement on license for 'INIA Alazan' maize	Institutional	Maize	INIA	CNFR	Producers' union gains license for INIA variety used by small and medium farmers. Benefits small core of producers engaged in family farming through CNFR and two associations: SFRO (Rural Development Society of Ortiz) and

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
						Calprose
2006	ACA participates in World Trade Organization (Geneva)	Policy	Rice	Private		Indicative of Uruguay's importance as a major global exporter of rice
2006	New varieties of peaches (Moscatos)	Plant breeding	Tree crops	INIA		Benchmark date for future use of varieties
2007	Release of first barley variety for the Northern zone	Plant breeding	Barley	INIA		Benchmark for new variety. Regional strategy
2007	Uruguayan President signed a decree imposing a moratorium for 18 month on review and approval of new biotech "events"	Policy	Biotech, maize, soybean	Public	Gov	Moratorium applied to both production and field testing. It was designed to give time for review of social as well as scientific issues pending development of a biosafety framework for Uruguay. The impact was greatest on maize since new varieties suitable for growth in Uruguay were not being approved. Stacked genes are considered a new event
2007	Release of strawberry variety 'INIA Guenoa'	Plant breeding	Horticulture	INIA		Variety that is early harvesting
2007	Creation of ANII	Institutional	Inter-ministerial	Public		Agency for promotion and funding innovation with resources augmented by major donors (IDB, World Bank, Spain and European Union). Areas of action include biotechnology, agro-industrial chains, environment and natural resources

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
2007	Publication of major thrusts of Public Policy in Science, Technology and ICT	Policy	Inter-ministerial	Public		Framework established three blocs of lines of action: 1) public policies and institutional arrangements, including funding for the National Agency for Research and Innovation (ANII); 2) strengthening of capacity for excellences in generating knowledge and technology and 3) development of innovation and technology transfer to private sector through clusters, consortia and networks
2007	Seed Unit expands presence in research stations	Capacity building	Seed system	INIA	Private sector seed companies	Seed Unit expanded beyond La Estanzuela and Treinte y Tres to Las Brujas and Salto Grande to continue work on onions, sweet potato and strawberries and to incorporate new commodities from research programmes
2007	Release of varieties of wheat with good yield and bread quality	Plant breeding, evaluation	Wheat	INIA, seed sector		Release of varieties that support resurgence of wheat production that began in 2003
2008	Forestry sector exports put Uruguay in 10th place globally in export of cellulose	Production benchmark	Agroforestry	Private		Area in forest (planted and native) reached 1.7 million ha. Exports reached US$800 million. Seeds sold in local markets increasing homogeneity of production

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
2008	Decree 353/08 of 21 July 2008 created 1) the GNBio (National Biosafety Cabinet); 2) the CGR (Risk Management Commission); 3) ERB (Evaluation of Biosafety Risk); 4) the CAI (Committee for Institutional Articulation) and 5) CCB (Consultative Committee on Biosecurity).	Institutional	All	Public	Gov	The five organizations serve respectively: 1) Ministerial approval; 2) technical implementation, 3) high level evaluation for each biotech event; 4) institutional harmonization of protocols applied in each sector; and 5) consultation with a broad range of stakeholders (specialized institutions, private sector, university, and civil society
2008	Policy of "regulated coexistence" announced	Policy	All	Public	Gov	Minister of Livestock, Agriculture and Fisheries announces that Uruguay would manage "a policy of regulated coexistence between transgenic and conventional crops"
2008	Decree of 8 July 2008 establishes a policy of "regulated coexistence between modified and non-modified plants"	Policy	Biotech	Public	Gov	Within the development framework called "Productive Uruguay" the State adopts a strategic role towards the use of biotechnology and creates GNBio (National Cabinet for Biosafety) [Modified 3 November 2008]
2008	INIA Biotech Unit built capacity in all research stations	Capacity building, institutional decentralization	Biotech	INIA		Centralized biotech services not meeting demand by decentralized programmes; falling costs permit expansion to all centres
2008	Release of strawberry variety 'INIA Ivapita'	Plant breeding	Horticulture	Public		Variety for organic production of strawberries

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
2008	Production of fine wool reaches 1.5 million kg	Production benchmark	Meat, dairy, wool	Private		Refer to benchmark date 1998 when programme launched
2008	Uruguay designated as host of CELARROZ and assumes presidency	Policy	Rice	Private		Reconfirms Uruguay's importance as a major global exporter of rice
2008	Evaluation of impact of rice and dairy programmes	Institutional	Rice, dairy	INIA	Procisur	Programme evaluation. Methodology that attempts to assess contribution of agronomic and management improvements to gains from varietal improvement
2008	Creation of Grupo Trigo: an INIA–Industry–Grower strategic alliance	Institutional	Wheat	Public–private		Links INIA research to seed multiplication and marketing sector represented by the CNST and seven large seed growing cooperatives. Follows strategy of rice sector in terms of integration
2009	INIA varieties of barley cover 50% of area planted	Production benchmark	Barley	Private		Refer to benchmark years of introduction
2009	Biotech capacity functioning in all centres	Capacity building	Biotech	INIA		Treinte y Tres: 1) incorporation of durable resistance to blast; 2) gene flow from Clearfield system; 3) cold tolerance in rice with FLAR; 4) MAS for culinary quality of rice Salto Grande: *in vitro* citrus and horticulture (microinjection or meristem culture) La Estanzuela: 1) install molecular marker lab; 2) Fontagro project on increasing productivity of wheat and potato in the

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
						face of climate change Tacuarembó: 1) molecular traceability of eucalyptus; 2) molecular identification of pathogenic fungi of genus *Mycophaerella*
2009	Decree of 8 June 2009 provides for Evaluation of Biosafety Risk (ERB)	Regulatory	Biotechnology	Public	Gov	ERB is a technical-scientific instance composed of a reduced number of experts proposed by the Commission for the Management of Risk (CGR) and named by the GNBio). It will make case-by-case decisions
2009	UINNOVA (Uruguay Innovates) created under Ministry of Innovation and EU	Institutional	Funding	Public	European Union	Cooperation agreement in science, technology and innovation between ANII (Uruguay) and the European Union. Two modalities exist: 1) funds for research groups, and 2) funds for business applicants
2009	GNBio approves introduction into national evaluation of cultivars of maize containing one of five biotech events	Policy	Maize	Public	Gov	Events approved for evaluation trials GA21, TC1507, NK603, BT11XGA21 or TC1507XNK603 were approved between 2006 and 2009 in Brazil on recommendation of GNBio. Decision continues policy that every new combination is a new event requiring approval. Evaluation is for agronomic qualities (INASE–INIA–UdelaR)
2009	INIA varieties of pasture and forage crops cover 50% of	Production benchmark	Pasture, forage	Private		Refer to benchmark years of introduction

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
	area planted					
2009	INIA varieties of rice cover 95% of area planted	Production benchmark	Rice	Private		Refer to benchmark years of introduction. Share of 'El Paso 144' 67%, 'INIA Tacuari' 10% and 'INIA Olimar' 18%
2009	Ministry of Foreign Affairs grants legal personality to CELARROZ	Policy, institutional	Rice	Public		Formalization of CELARROZ as a legal body
2009	Programme of electrification extended to all rice areas of country	Policy, infrastructure	Rice	Public		Public investment in infrastructure of benefit to productive sector, particularly rice
2009	Call for proposals under Innovagro to promote research, development and innovation in agriculture, livestock and agro-industry.	Institutional	Science, technology, innovation	Public	Private	Innovagro is the first sector fund for agro-industry under ANII in cooperation with INIA, Ministry of Livestock, Agriculture and Fisheries and Ministry of Industry, Energy and Mining. It benefits from a cooperative agreement in science, technology and innovation between ANII (Uruguay) and the Center for Industrial Technological Development (CDTI, Spain). Two modalities exist: 1) funds for research groups, and 2) funds for business applicants.
2009	INIA varieties of wheat cover 30% of area planted	Production benchmark	Wheat	Private		Refer to benchmark years of introduction
2010	Soybean area and value of exports rises to principal export.	Production	Soybean	Private		Value of soybean exports expected to exceed value of rice exports for first time (expected to be US$456 million)

Year	Description of event	Nature of event	Crop	Sector	Partners	Impact or benchmark
2010	Wheat exports expected to reach 1.7 million tonnes	Production benchmark	Wheat	Private		In 5 years Uruguay passed from importing wheat to exportable surplus of US$350 million potential

Approach based on Elliott (1988). Individual entries compiled from annual reports, websites of organizations and companies, and miscellaneous reports.

Annex 3. INIA programmes and units.

Programmes	Focus/concern	Research related	Status
Commodity subsector programmes: value chains			
Dryland Crops	Wheat, barley, soybean, sunflower, maize, rapeseed	Breeding for natural resistance to disease, soil analysis	Share of INIA varieties in total area planted: Barley 50%, wheat 30%
Rice		Breeding for yield, milling quality, integration of crop management	Share of INIA varieties in total area planted: rice 95%
Dairy	Quality, diversification of products	Selection, animal health, nutrition, management of value chain, environmental sustainability	Over last 30 years, production tripled; 50% of production exported from sector
Meat and Wool	Viability of family enterprises; introduce high-value product in basaltic regions	Sustainable intensification, quality of meat, fine merino wool in areas with no alternatives	Uruguay has highest density of animals/humans in world
Forestry Production	Plantation in fast-growing species	Genetic improvement of eucalyptus, pine, rapid multiplication of planting material	Value of exports have tripled in sustainable manner
Horticulture	Quality, nutrition, safety, profitability of domestic production	Strawberries, onions, other. Production systems (integrated, organic), traceability	25 000 ha mostly in family enterprises account for 10% of number of establishments. 600 ha under protection. Supply capital with fresh production
Fruit and Vine	Small and medium family orchards	Genetic improvement: taste, aroma, nutrition, appearance. Propagation *in vitro*. Evaluation and introduction of cultivars	
Citrus	Export chain. Quality, safety, traceability, conserve varieties and rootstock	Management and limitation of agrochemicals. Biological control. Prediction models, adaptation to climate change	Annual production 300 000 tonnes, 50% exported. Sector has 400 enterprises and 10 000 workers

Thematic/cross-cutting programmes: strategic areas

Pastures and Forage	Productivity, sustainability, conserve biodiversity. Genetic improvement. Weed control	Creating, releasing, multiplying new grasses and legumes; systems for intensive and extensive livestock; evaluation of mixed and pure pasture. Develop indicators to monitor natural cover and degradation in vulnerable areas	15% of area in cattle is on improved pastures. 50% of this area is in INIA products
Family Production	Cross-cutting opportunities for 35 000 smaller family enterprises	For 35 000 family farms develop differentiated products: fruit, medicinal plants, organic horticulture, pork, integrated systems, potential crops for ethanol (castor bean, sweet potato)	Fruit satisfies domestic market and growing exports. Growth of high value/export production from family farms
Sustainable Development	Relation between production systems and environment	Precision agriculture, direct seeding, agroforestry for energy, impact of chemicals	Commodity subsectors (e.g. rice–pasture) have achieved high productivity and low chemical use due to varieties and management research

Technical units

Biotechnology Unit	Services and support incorporated in INIA programmes Participation in agrobiotech platforms with UdelaR, Institut Pasteur, IIBCE and LATU	Tissue culture for vegetatively propagated crops Generation of genotype by phenotype information of interest to productivity. With agrobiotech platforms: study biotic and abiotic factors affecting agriculture; nitrogen fixation, growth promoters Regional programme for Mercosur (BiotecSur)	Micropropagation *in vitro* (fruit, horticulture, forest species) Integrative genomics platform: capacity-building in functional and structural genomics. In quantitative genomics for meat, dairy and wool study molecular markers for resistance to intestinal parasites in Australian Merinos BiotecSur project on improvement of soybean against biotic and abiotic stresses In forage: generation of inter-specific hybrids of tetraploid *Lotus*
Seed Unit	National competitiveness through genetic purity, quality and quantity of material	Supply seed sector with basic seed in key crops Varietal maintenance of public protected varieties: prebasic seed conservation Propagation of promising material Seed pathology laboratory.	Basic seed (number of varieties): rice 4; wheat 7; barley 2; maize 1; forage legumes and grasses 13; trees 3. Propagation of promising lines: wheat 12; rice 4; barley 2; forage legume and grasses 8. Multiplication: agreements with seed companies for publicly protected lines: white clover 2; alfalfa 1; and wheat 1
Agro-climate and Information Unit	Identification of impact of climate change and means of adaptation Information on water balance in soil National index of vegetative cover	Development of integrated GIS system of soil, water and climate information Simulation models based on remote sensing to estimate forage production Evaluation of impact of climate change on natural pastures and rice System for prediction and prevention of fusarium and mycotoxins in grain	Regional project on climate change and agricultural production systems in LAC: response and strategies

Communication and Transfer of Technology Unit	INIA "presence", publications, website, major events	INIA-wide representation	In 2008: approx. 300 events with 22 000 participants; 168 publications (posters, diffusion materials, scientific articles) ; field days, conferences; some research on participatory innovation; consultation
International Cooperation Unit	Intensify international cooperation with centres of excellence; Adopt global science in line with conditions of country	Agreements, projects and contracts with major partners: Argentina, Australia, Brazil, EU, Japan, New Zealand, Norway, Spain, USA	Examples of project relating to capacity building: 1) INIA–EMBRAPA to develop evaluation criteria for competitive grants; 2) Cornell: climate change; 3) Norway: create a platform on integrated water management; Japan: Strengthen system of environmental evaluation and registry of phytosanitary products; 4) China; training of technician on hybrid rice
Information Management Unit	Ensure correct use of IT platforms	Maintain infrastructure; manage contracting of specialist support; implement integrated management system; document management	Unit consolidated in 2008

Source: Adapted from INIA (2009) and El Pais (2009).

Annex 4. International affiliations of members of the Chamber of Seeds, Uruguay.

CUS member	Parent company	Principal areas of operation	Notes
Agritec S.A.		Agrochemical, fertilizers, horticultural seeds, adjuvants and agro-textile	Soybean, millet, corn, alfalfa and ryegrass seeds
Agroapoyo S.A.		Contract production and commercialization of seeds and grains	Nidera Semillas logo appears on website
Agropick. S.A.		Legumes, grasses, other forage	Maize, sunflower, summer sorghum, summer forage
Agrosan S.A.	PGG Wrightson	Seed production, distribution and marketing; supported by research internationally.	Regional base and distributor Pioneer brands and Dupont Agrichemical
Agroterra S.A.	Monsanto		
Barraca Jorge W. Erro S.A.	Don Mario	Don Mario is leading marketer of soybean seeds in Argentina accounting for 38% of market. Other: alfalfas, oats, *Lotus*, white and red clovers	Don Mario accounts for 40% of controlled sales of soybean seeds in Uruguay; international exporter
Bayer S.A.	Bayer	Agricultural chemical for protection, crop improvement, biotechnology and treatment of seeds, environmental health, and control of diseases and vectors	Integrated solutions from Bayer CropScience based on seed, innovative crop protection products and comprehensive advice Support fruit and vegetable growers in their efforts to market their products internationally
Beltrame CIA. S.A.	Veluvier	Vegetables: tomato, onion, carrot	
Calvase		Wheat, oats, forage, maize, sorghum, soybean, rice	
Coopar. S.A.		Rice agro-industry situated in Uruguay	Rice processed and packaged for table
Crop Uruguay S.A.	Cargill (2005)	Production: Soybean: technical support, testing, forward contracts to producers Marketing: Soybean: China, Egypt, Europe; Wheat: Middle East; Sunflower: US	Rapid insertion of Uruguay in new international markets
Estero S.A.		Uruguayan seed company: production, development, trading forage seeds, hybrid maize, sorghum	Research field El Pedregal: performance trials, seed production for regional markets and

CUS member	Parent company	Principal areas of operation	Notes
			export
Fadinur S.A.	La Tijereta, Argentina	Marketing of hybrids and agrochemicals. Maize hybrids, sunflower, soybean, sorghum	For Monsanto served as instrument to penetrate low-cost end of input market
Fadisol S.A.	Pannar		No information
Gentos Uruguay S.A.	Gentos Argentina	Development of private forage (Gentos-AgResearchm, Gentos Biosemillas)	Grasses, legumes, sorghum (forage and grain)
Lebu SRL	IPB	Hybrids of maize, sunflower, sorghum	Seed for Uruguayan market, Paraguay, and world market
Malteria Uruguay S.A.	Ambev	International: Malting barley for domestic and Mercosur market	Integrated value chain
Malteria Oriental S.A.	Ambev	International: Malting barley for domestic and Mercosur market	Integrated value chain
Millacar S.A.		Alfalfas, oats, grasses, legumes	
Nidera Urguguay S.A.	Nidera Netherlands Regional HQ In Argentina	Trading in grains, oilseeds, vegetable oils and meals; feedstuffs, rice and ocean transport. Other related activities include the operation of elevators, processing plants, and vegetable oil refining and bottling	In Argentina, Nidera is also engaged in the R&D of seeds and in the handling of a wide range of agricultural inputs
Praderas Azules S.A.			No information
Procampo Uruguay S.R.L.	KWS (Germany)	Forage, oats, wheat, maize, sorghum, sunflower, soybean	
Rutilan S.A.	Dow	Fungicides, herbicides, insecticides	
Saman	Camil (Brazil)	Uruguayan company: 50% share in rice milling, seed production, processed rice products Global trader	Camil purchase of Saman and Tucapel (Chile) to enter global market
Saudu			No information
Semillas Uruguay S.A.	Don Mario	Don Mario is leading marketer of soybean seeds in Argentina	Don Mario accounts for 40% of controlled sales of soybean seeds in Uruguay
Seminium Uruguay S.A.	La Tijereta, Argentina	Production and marketing of hybrids and agrochemicals. Maize hybrids, sunflower, soybean, sorghum	For Monsanto served as market penetration for lower-cost inputs
Wrightson Pas S.A.	Wrightson, NZ.	Forage, oats, wheat, maize, sorghum, sunflower, soybean	

CUS member	Parent company	Principal areas of operation	Notes
Yalfin S.A.	Syngenta	Exclusive representative NK Seeds; maize, sunflower, soya, sorghum	Adapted varieties for each zone of Argentina; tested in Uruguay