CHAPTER

10

Improving Rice Production Systems in Latin America and the Caribbean

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Contents

Abstract

The Latin American Fund for Irrigated Rice (FLAR, its Spanish acronym) is a public–private partnership between local rice institutions and the International Center for Tropical Agriculture (CIAT, its Spanish acronym), which was formed in 1995 with the aim of improving people's lives through improved rice production. FLAR has a holistic approach to improving rice production, taking into account farmers' economic, social, and environmental situations. New high-yielding, high-quality varieties, improved crop management practices, and the use of water harvesting to expand irrigated production have been the main FLAR interventions among its 16 associated countries. Forty new varieties have been released in 13 countries to the end of 2011 and many more are in the pipeline. Farmer-to-farmer transfer and extension programs to improve crop management have been developed in 14 countries, and a pilot project on water harvesting to expand irrigation on small-scale, resource-poor farms is under way in Central America. FLAR has successfully developed eco-efficient technologies that helped the Latin American rice sector produce more rice, with fewer inputs, at lower costs per unit of output, contributing to enhancing the well–being of the rural and urban poor in the region.

Introduction

Rice is a relatively new crop in Latin America and the Caribbean (LAC). Although it was introduced into the region in the sixteenth century by Spanish colonists, it was not widely grown until the twentieth century. It is now grown throughout the region, in a wide range of agroecosystems,

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ranging from upland systems in the Brazilian Cerrados and some hilly areas of Bolivia, Colombia, and Central America to high-tech irrigated systems in the Southern Cone region. About one million farmers in the region, 80% of them resource-poor smallholders, depend on rice as their main source of energy, employment, and income (Maclean et al., 2002).

Rice is now the most important food grain in most of the tropical areas of LAC, where it supplies more calories in people's diets than wheat, maize, cassava, or potatoes, and is also the leading source of protein for the poorest 20% of the population in tropical areas (Maclean et al., 2002). The crop provides an average of 27% of daily calorie intake in LAC as a whole, ranging from 8% in Central America to 47% in the Caribbean region (FAOSTAT; http://faostat.fao.org).

Total production of paddy rice increased from around 8 million tons in 1961 to more than 28 million tons in 2009, an increase of over 250% (Table 1). Over this period the area under rice increased by only 35%, hence the majority of the increase in production came from yield gains. However, there is still a negative balance between production and consumption in the region as a whole.

There is thus clearly a need to increase rice production in the region. It is vital, however, that this is done through eco-efficient production systems. Eco-efficiency implies producing more while using fewer resources and creating less waste and pollution. Eco-efficient rice production should be profitable, competitive with other agricultural or commercial activities, and ecologically sustainable. It should also be resilient in the face of climate change and socially equitable, giving small-, medium-, and large-scale producers access to new practices and technologies. In summary, eco-efficient rice production allows farmers to derive more benefits from rice cultivation using fewer resources.

The Latin American Fund for Irrigated Rice (FLAR, its Spanish acronym) is a public–private partnership between local rice institutions and the

Table 1. Paddy rice area and production for selected countries in Latin America and the Caribbean, 1961 and 2009.

	Area ('000 ha)			Production ('000 t)		
	1961	2009	Change (%)	1961	2009	Change (%)
South America						
Argentina	46	194	322	149	1,334	795
Bolivia	24	180	650	34	396	1,065
Brazil	3,174	2,872	-10	5,392	12,651	135
Chile	38	24	-37	105	127	21
Colombia	237	543	129	474	2,985	530
Ecuador	95	395	316	203	1,579	678
Guyana	106	215	103	215	554	158
Paraguay	8	50	525	19	215	1,032
Peru	81	405	400	333	2,991	798
Uruguay	17	161	847	61	1,287	2,010
Venezuela	58	250	331	81	1,330	1,542
Subtotal	3,884	5,289	36	7,066	25,449	260

(Continued)

Table 1. (Continued.)

	Area ('000 ha)			Production ('000 t)		
	1961	2009	Change (%)	1961	2009	Change (%)
Central America						
Belize	1	5	400	1	21	2,000
Costa Rica	48	63	31	60	260	333
El Salvador	9	6	-33	18	40	122
Guatemala	9	8	-11	13	23	77
Honduras	9	9	0	12	45	275
Mexico	146	54	-63	333	263	-21
Nicaragua	24	74	208	39	335	759
Panama	100	107	7	109	242	122
Subotal	346	326	-6	585	1,229	110
Caribbean						
Cuba	150	216	44	207	564	172
Dominican Republic	58	182	214	113	848	650
Jamaica	3	0	-100	5	0	-100
Trinidad and Tobago	5	1	-80	10	2	-80
Subtotal	216	399	85	335	1,414	322
Total	4,446	6,014	35	7,986	28,092	252

SOURCE: FAOSTAT (http://faostat.fao.org).

International Center for Tropical Agriculture (CIAT, its Spanish acronym). It was established in 1995 to improve people's lives through the development of improved rice technology (Zorrilla, 2010). By 2011 more than 30 institutions, including farmers' associations, national research institutes, and private companies, in 16 countries were participating in FLAR.[3] Since its establishment FLAR has implemented programs to promote use of improved varieties and management practices, and better use of natural resources.

This chapter summarizes some results from the main interventions FLAR and its members are promoting, with special emphasis on their impact on eco-efficiency.

[3] FLAR Members: Argentina – National Institute of Agricultural Technology (INTA), Copra SA (private company), Adeco Agropecuaria SA (private company); Bolivia – National Rice Corporation (CONARROZ); Brazil – Rio Grande Rice Institute (IRGA); Colombia – National Federation of Rice Growers (FEDEARROZ); Chile – Federation of Rice Producers (FEDEARROZ); Costa Rica – Seeds of the New Millennium (SENUMISA); Dominican Republic – Genetics of Rice (GENARROZ); Ecuador – Independent National Institute of Agricultural Research (INIAP); Guatemala – Guatemalan Rice Association (ARROZGUA); Guyana – Guyana Rice Development Board (GRDB); Honduras – Directorate of Agricultural and Livestock and Science and Technology (DICTA), Honduran Association of Rice Producers AHPRA; México – Mexican Rice Council (CMA); Nicaragua – Nicaraguan Association of Rice Farmers (ANAR); Panama – Panamanian Rice and Grain Federation (FEDAGPA), Panama Institute of Agricultural Research (IDIAP), CONAGRO SA (private company), Seeds of Coclé (SECOSA; private company); Uruguay – National Institute of Agricultural Research (INIA), Association of Rice Growers (ACA); Venezuela – National Rice Foundation (FUNDARROZ); International Center for Tropical Agriculture (CIAT).

Rice Breeding: New Varieties that Produce More Rice with Fewer Inputs

The so called "green revolution" in rice started with the release of the semi-dwarf variety IR8 in 1966 by the International Rice Research Institute (IRRI) in the Philippines (Hargrove and Cabanilla, 1979; Khush, 1999). Less than two years later IR8 was introduced in Colombia by Peter Jennings and a pioneering breeding program was initiated by CIAT, the Colombian Institute of Agriculture (ICA, its Spanish acronym), and the National Federation of Rice Growers (FEDEARROZ, its Spanish acronym). This program soon developed new semi-dwarf varieties that increased rice production in Colombia and in the whole region. Average yields in Colombia rose from 1.5 t/ha in 1965 to 4.4 t/ha in 1975 (Scobie and Posada, 1977). Between 1968 and 1990 rice yields in Latin America increased by 20% due to new semi-dwarf varieties (Muchnik, 1985).

Between 1975 and 1995 some 250 improved rice varieties were released in LAC. The adoption of these improved varieties enhanced food security and reduced the real price of rice (Maclean et al., 2002).

FLAR's goal is to develop a cooperative and efficient breeding program aimed at producing and releasing high-yielding varieties with desirable agronomic and grain quality traits. The program is based at CIAT headquarters in Palmira, Colombia, but is administratively independent of the Center's breeding program. This arrangement gives FLAR immediate access to improved material developed by the Center and provides a direct link with other international research institutions, such as IRRI.

FLAR's breeding program focuses on developing varieties for tropical and temperate zones. FLAR breeders introduce new materials, make around 800 hundred triple crosses a year, advance and select 5000 to 6000 breeding lines in different environments, and produce and select elite breeding lines (FL lines). Breeding and initial evaluation are done at CIAT Headquarters and the Santa Rosa Research Station near Villavicencio in Colombia's Llanos Orientales or Eastern Plains. Elite lines are selected annually in nurseries called "VIOFLAR Tropico" and "VIOFLAR Templado" and distributed to FLAR members. Members evaluate and further select these FL lines in their local environments, register lines that perform well, and release them as new varieties. The first variety of FLAR origin was released in 2003, and a total of 40 new cultivars have since been registered in 13 countries up to the end of 2011.

FLAR members invest their own resources in the program and contribute to the breeding strategy. This encourages greater engagement between the members and the network. One common problem faced in open germplasm networks is the very poor feedback of information on the performance of lines at the different testing sites. In contrast, FLAR members provide performance information on about 80% of the material received, providing FLAR breeders with the feedback needed to fine-tune their breeding strategies.

The program is subdivided into tropical and temperate regions. The main common breeding objectives in both subprograms are: high yield potential; resistance to rice blast [*Magnaporthe grisea* (Herbert) Barr (anamorph *Pyricularia grisea*)] and other fungal diseases; resistance to lodging; high milling and cooking quality; and tolerance of delayed harvest (i.e. grain retention). For the tropics the program is also breeding for resistance to rice hoja blanca virus and its insect vector [*Tagosodes orizicolus* (Muir)]. For the temperate region tolerance to low temperatures is an important trait. Planting early in the season is critical in the Southern Cone to allow flowering to coincide with peak solar radiation and ensure good grain filling. Thus, cold tolerance at seedling stage is needed, as is some cold tolerance at the reproductive stage, because low temperatures may occur any time during the season.

The following are some examples of the characteristics and uptake of the varieties developed through FLAR.

Venezuela 21 was the first variety from FL material to be released by a FLAR member

(FUNDARROZ, 2003). It has excellent yield potential (8 t/ha) and yield stability across seasons, much better disease tolerance than checks, and good grain quality. By 2009 it accounted for 31.6% of the total rice seed market in Venezuela.

The Panama Institute of Agricultural Research (IDIAP, its Spanish acronym) released two FL-based varieties in 2005: IDIAP 54-05 and IDIAP 145-05 (Camargo, 2006). Both have good resistance to the main diseases occurring in Panama (rice blast, and panicle blight caused by *Burkholderia glumae*), give high yields under both rainfed and irrigated conditions, and have excellent grain milling quality. In the 2010/11 cropping season each of them was planted on more than 20% of the country's rice area.

In Costa Rica, Seeds of the New Millennium S.A. (SENUMISA, its Spanish acronym) released Palmar 18 in 2006. The variety has high yield potential under both irrigated and rainfed conditions, good tolerance to main diseases (rice blast, panicle blight, and grain discoloration caused by a fungus complex), a short growing cycle, and excellent grain quality. By 2009 it accounted for 46.7% of the certified rice seed produced in Costa Rica (Oviedo, 2010).

The Guyana Rice Development Board (GRDB) released GRDB FL 10 in 2009. In trials between 2008 and 2010 GRDB LF 10 outyielded the check variety by an average of 28.3% across spring and autumn cropping seasons (Persaud, 2010). By the beginning of 2011 the variety covered 15% of the area planted to rice in Guyana.

Genetics of Rice S.A. (GENARROZ, its Spanish acronym) released Jaragua FL in the Dominican Republic in 2010 (Moquete, 2010). This variety was selected from FL material introduced in 2007. Jaragua FL has high yield potential (more than 8 t/ha) under a range of planting systems and environments, excellent milling performance (62–64% of whole rice), very low percentage of "white belly" (opaque endosperm), and excellent cooking quality. It also has very good tolerance to major fungal diseases and some tolerance to saline and acidic soils.

Agronomy: Improving Eco-efficiency by Crop Management

Eco-efficient agriculture depends not only on good varieties, but also on several other factors, such as sustainable use of natural resources, farmer skills, and crop management techniques. Farmers' yields in LAC remain well below the yield potential of the varieties grown, largely as a result of suboptimal crop management (Pulver, 2001). Bridging this yield gap could increase rice production in LAC by 27% (Sanint, 2004).

In 2003, FLAR, with financial support from the Common Fund for Commodities (CFC), initiated a technology transfer program in the state of Rio Grande do Sul, Brazil, and Portuguesa and Guarico states, Venezuela, aimed at reducing this yield gap. The program later expanded to include Argentina and Uruguay in the Southern Cone and Costa Rica and Nicaragua in the tropical zone.

The program focused on six basic strategic management practices:

1. Appropriate planting time
2. Low seeding rate
3. Use of high-quality seed and seed treatment against insect pests
4. Early weed control
5. Fertilizer management
6. Irrigation management

These practices were usually complemented by location-specific practices developed by local research and/or through farmer participatory research at the trial sites.

FLAR employed a farmer-to-farmer extension approach, using a farmer leader to transfer the technology to other growers. At each location an initial survey of the rice sector was conducted to identify the main technological weaknesses. Innovative farmers who had the capacity and willingness to communicate their experiences were then selected. These farmer-leaders receive extensive training in the recommended practices, and demonstration plots were established on the farmer-leader's land. Groups of growers in the vicinity of each pilot farm visited the demonstration plots regularly and discussed their observations with the farmer-leader, often leading to modification of the recommended practices. These growers were then assisted in adopting the recommended practices.

Following the success of the initial project, activities were extended to Bolivia, Chile, Dominican Republic, Ecuador, Guyana, Honduras, Mexico, and Panama.

In total, the program worked with nearly 8000 farmers growing nearly 600,000 ha of rice, and achieved yield increases of between 0.6 and 1.7 t/ha (Table 2).

The State of Rio Grande do Sul in Brazil, and neighboring areas of Argentina and Uruguay provide good examples of the impact of improved crop management on rice production. Since early 2000 this region has shown a revolution in rice production driven by improved crop management. FLAR has had different grades of involvement in this process working with the Rio Grande Rice Institute (IRGA, its Portuguese acronym) in Brazil, the National Institute of Agricultural Technology (INTA, its Spanish acronym) in Argentina, the National Institute of Agricultural Research (INIA, its Spanish acronym) in Uruguay and the Rice Farmers Association (ACA, its Spanish acronym) also in Uruguay to boost rice production. As a result of these programs, total annual rice production increased from an average of 7.0 million tons in 2000–2002 to 9.4 million tons in 2006–2008, an increase of 35% (Figure 1). Over the same period, yield increased from 5.4 t/ha to 7.2 t/ha, an increase of 33%, while the area planted has been almost stable. Thus, the increase in production was largely the result of increased yields. Over this period there was little change in the varieties planted, and hence the production gains are the result of improved agronomic practices.

Table 2. Summary of activities and estimated impacts from FLAR Agronomy and Technology Transfer Program. (Carmona and Pulver, 2010).

Country	Period[1]	Demonstration Plots	Field Days	Trained Farmers	Area of Impact[2]	Yield Increase[3]
Argentina	2005-08	27	34	150	40,000	1.5
Bolivia	2006-10	20	15	920	10,000	1.5
Brazil	2003-06	121	346	4,895	414,240	1.7
Chile	2010	8	4	120	650	0.6
Costa Rica	2005-10	45	20	150	9,000	1.6
Dominican Republic	2008-10	20	2	20	2,000	1.0
Ecuador	2006-07	20	4	100	1,000	1.3
Guyana	2006-08	44	88	200	10,000	1.0
Honduras	2006-07	22	3	55	3,000	0.8
Mexico	2007-10	55	15	330	10,000	1.8
Nicaragua	2005-10	20	20	120	10,000	1.5
Panama	2006-10	20	10	80	5,000	1.2
Uruguay	2005	13	18	45	16,000	1.5
Venezuela	2003-10	250	148	570	40,000	1.3
Total		685	787	7,755	570,890	

1. Period of direct intervention in the country.
2. Estimated annual area attained by the program at the end of its intervention.
3. Yield increases estimated over the area associated with the program (t ha^{-1}).

Figure 1. Combined production, area and yields in the irrigated rice region of Southern Cone associated with FLAR: Rio Grande do Sul State in Brazil, Argentina, and Uruguay.
SOURCE: annual statistics from Instituto Riograndense do Arroz (IRGA), Brazil; Asociación Cultivadores de Arroz (ACA), Uruguay; Asociación Correntina de Productores de Arroz (ACPA), Argentina.

Water Harvesting: Taking Advantage of an Underexploited and Abundant Natural Resource

Less than a quarter of the rice area in LAC is irrigated, ranging from 79% in Brazil to only 1% in Mexico. However, overall the region is well endowed with water resources (Table 3). Even Mexico, nearly one-third of which is arid, has extensive water resources in its central and southern areas. Additionally, most of the renewable water resources in Latin America are surface water, which is essentially from rain water. Consequently, the problem in Latin America is not scarcity of water, but its effective use to produce food and reduce poverty in the rural areas.

FLAR has been investigating the potential of water harvesting to increase the use of irrigation in upland rice production. In 2008, FLAR and CIAT initiated a project on “Transformation of upland to irrigated rice through use of water harvesting in Costa Rica, Mexico and Nicaragua”. The project is sponsored by CFC and co-sponsored by SENUMISA in Costa Rica, the Mexican Rice Council, and the Nicaraguan Association of Rice Farmers.

This pilot project is introducing proven water harvesting techniques, training local staff to identify suitable sites for catchment facilities, and demonstrating the economic benefits of a diversified rice-based production system under irrigation. The target audience is small-scale farmers currently involved solely in rainfed agriculture. The project is focusing on simple, low-tech, low-cost water harvesting techniques, essentially small and medium-sized earth dams constructed in farmers’ fields to take advantage of

Table 3. Renewable water resources in several Latin American countries compared to major rice producing countries of Asia.

Country	Water resources: total renewable (actual) (km^3/year)	Surface water: produced internally (km^3/year)	Water resources: total renewable (actual) (m^3/capita per year) (2000)
Central America and Mexico			
Costa Rica	112	75	27,932
Honduras	95	86	14,949
Mexico	409	361	4,634
Nicaragua	196	185	38,787
Panama	148	144	51,814
South America			
Argentina	814	276	21,981
Brazil	8,233	5,418	48,314
Colombia	2,132	2,112	50,635
Ecuador	432	432	34,161
Paraguay	336	41	61,135
Peru	1,913	1,616	74,546
Uruguay	139	59	41,654
Major Rice Countries in Asia			
Bangladesh	1,210	83	8,809
China	2,829	2,711	2,258
India	1,896	1,222	1,880
Indonesia	2,838	2,793	13,381
Philippines	479	444	6,332

SOURCE: FAO AQUASTAT 2000: Renewable water resources in the world by country.

topography and an adequate water catchment basin. These dams allow farmers to harvest and store rain water that can then be used for full or supplemental irrigation by gravity. The ponds can also be used for fish production, bringing another high-value product to farmers.

Harvesting water during the rainy season allows for high yielding irrigated agriculture during the high solar radiation dry season and doubles job opportunities in regions like northern Nicaragua where there are 6 months with minimum activity on the farms.

In trials in Mexico, despite being established too late in the season (April/May 2010) for optimum yield, irrigated rice still yielded 65% more than neighboring non-irrigated rice crops (Table 4). If the crops had been established in February as planned, yields of 10 t/ha would have been achievable.

In Jalapa Department in north-central Nicaragua one farmer planting irrigated rice during the dry season reported a yield of 10.5 t/ha, and a net profit of US$2,000/ha. This compares with net profits of less than US$100/ha for rainfed maize and less than US$50/ha for rainfed beans grown during the rainy season.

These initial results demonstrate the potential of water harvesting and storage to diversify smallholder farmers' production options and to boost income and food security.

Table 4. Yield of rainfed and irrigated rice at two sites in Mexico, 2010.

Location	Yield, kg/ha	
	Rainfed	Irrigated
Escuela Texistepec, Veracruz	4,362	6,800
Carlos Contreras, Cosamaloapan	3,623	6,343
Mean	3,993	6,572
Mean increase in yield with irrigation (%)		65

Concluding Remarks

FLAR has developed a holistic approach to improving the rice industry in LAC, addressing genetics, crop management, and natural resources utilization. Being a public-private alliance in which most rice farmers' organizations are represented along with national research institutes and private companies, it helps not only small-scale, resource-poor rice growers, but also the whole rice sector.

There are enormous challenges ahead, including rising food demand, competition for land, the need for reducing environmental footprint, and dealing with climate change. New products from agricultural research addressing yield potential, resistance or tolerance to changing pest and diseases, resistance to abiotic stresses and new quality requirements will be essential to cope with them. FLAR and its many members from almost all Latin American countries provides a platform through which the products of research can be rapidly extended to farmers, increasing food production, reducing rural poverty, and enhancing food security.

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