The Current Situation and Issues on Rice Production in Latin America and the Caribbean

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1. Introduction

Global production of the three main staple cereals (rice, wheat and maize) has outpaced population growth over the past 30 years. This expansion has been primarily the result of important gains in productivity, a process known as the Green Revolution (Table 1). Several indicators confirm the results: higher per capita cereal supplies, substantial yield increases and lower prices available to consumers world-wide. Seed-borne technologies proved to be efficient and universal in reach and scope. The least privileged groups have benefited significantly; for them, these staples represent the main source of calories and proteins and an important part of the household budget. However, this progress has been insufficient to solve the problem of chronic malnutrition of about one billion people on this planet. Food production is an important component of the strategy for feeding the population; the other two basic components are food distribution and population growth. Producing enough food to be available to everyone is a part of the broader goal of reaching sustainable development. In cultivated areas, many pests are now harmless against the new resistant cereal varieties; fighting pests does not resort to higher doses of pesticides per unit of land. Perhaps equally important are the invisible indicators. Increased productivity implies that millions of hectares were not disturbed to accomplish this challenge of increasing per capita food supplies amidst a rapidly growing population.

Table 1. Annual rates of growth for cereals in the world, 1967-97[a].

	Rice	Wheat	Maize
Production	2.5	2.3	2.6
Yields	2.1	2.2	1.9
Area	0.4	0.1	0.7

SOURCE: Calculations based on FAOSTAT, 1998.

a. Population rate of growth calculated at 1.7.

The accomplishment, to a large extent, is thanks to perseverance in the search for better varieties, a task that counts on an increasing pool of new and alternative tools and powerful allies in the fields of science, technology and communications. Our knowledge of the complex spheres of genetics and molecular manipulation is being expanded to reap the benefits for the endless task of feeding a growing population within the requisites of sustainable development. Alongside this progress, important advances were also made in irrigation, agrochemicals, integrated crop management (ICM), mechanisation and post-harvest techniques. These changes, coupled with stronger institutional models, are behind the evident production success as several indicators summarise. The negative aspect includes the increased risk of epidemics because of narrow genetic bases, and the crop management problems associated with more intense cropping systems that led in some cases to soil degradation, declining water quality and health-related problems among others.

Crop management has an important behavioural component. In this sense, it should be clear that in most cases "the root cause of this environmental degradation has been mistaken economic policy – not modern, science based technology" (Borlaug, 1997). A major challenge for the future is to manage environmental risks without compromising on the productivity gains achieved. Increased productivity is a necessary but insufficient condition to ensure food availability to everyone in a sustainable manner. The use of general indicators (e.g., poverty, food availability and rural income) is widely believed appropriate to judge the success of scientific accomplishments in biological research. This use is inadequate and leads to improper focus in project evaluation. More emphasis needs to be placed on the progress made in specific products (e.g., varieties, yield, resistances and quality). Science-based technologies have an edge on contributing efficient elements for a successful strategy of augmenting the yield per unit area and adopting highly productive and environmentally viable cropping technologies.

1.1 Rice in Latin America and the Caribbean (LAC)

The present world rice production is about 570 million tons of paddy, of which Latin America produces 3.6%, planting 4.1% of the total area. The harvested area of Latin American rice is about 6.1 million ha (FAOSTAT, 1998). Advances in global rice production over the past 30 years show similar patterns to those observed in wheat and maize. Rice is the leading staple food crop in the world: one-third of the world's population depends on rice for nearly two-thirds of its food. Annual rates of growth are almost identical in Asia and in LAC, with the contribution from enhanced productivity explaining about 90% of the growth (Table 2). Over the period 1967-95, some 297 new rice varieties have been released in LAC (about 10 new varieties every year) most of them (90%) targeted to flooded environments. Of the new varieties, 40% came from crosses made at CIAT, 11% at the International Rice Research Institute (IRRI) and several of the rest have parentage from International Agricultural Research Centre (IARC) progenitors (Table 3). Modern semidwarf rice varieties (MSVs) now account for 93% of all flooded rice production, itself representing more than 80% of total rice production in the region (Table 4). Average yields in flooded areas have risen from 3.3 t ha^{-1} in the mid-1960s to 4.6 t ha^{-1} in 1995; total rice production doubled between 1967 and 1995 to reach about 20 million tons of paddy rice (Table 5), making the region largely self-sufficient in rice.

The role of rice in agricultural and rural development has been noteworthy. The cereal was a key pioneer crop in the early part of the century because traditional and improved tall rice varieties were well adapted to the newly opened, frequently acid soils of the savannas, the lowlands and the forest margins. Rice has an important multiplier effect on the frontier economies over and above the crop activity. Other important economic benefits include milling, mechanisation, commercialisation, professional services and indirect effects on employment, investment and growth. The upland rice area planted peaked at over 6.0 million ha in 1976, when it accounted for over 75% of the rice area in the region. With the widespread adoption of the new semidwarf varieties in the 1970s, upland rice lost its competitiveness against the rapidly growing yields and the descending real unit production costs of the flooded rice areas. Currently, upland rice has plummeted to 2.5 million ha (40% of the rice cultivated area in LAC), mostly in the Brazilian *cerrados*, as rice production increasingly concentrates in the more stable lowlands under irrigated and flooded conditions, driven by the higher productivity of these systems.

Table 2. Rice: Annual rates of growth by continent, 1967-97.

Continent	Production	Area	Yields
Latin America and the Caribbean	2.5	0.4	2.1
Asia	2.5	0.4	2.1
Africa	2.8	2.2	0.6
North America	2.5	1.4	1.1
World-wide	2.5	0.4	2.1

SOURCE: Calculations based on FAOSTAT, 1998.

Several institutional developments are central to these accomplishments:

- The private sector is becoming more involved in rice research and extension through formal associations that consolidated strategic alliances with public institutions both national and international.

- The region is linked through CIAT to the world's premier source of rice germplasm, IRRI.

- A strong, regionally relevant rice improvement program developed in the 1970s and 1980s through a productive partnership of CIAT, the Federación Nacional de Arroceros de Colombia (FEDEARROZ), and the Instituto Colombiano Agropecuario (ICA) in Colombia.

- CIAT's regional rice program, national programs and producers in major rice producing countries of LAC cooperate closely.

Table 3. Rice varieties released in Latin America and the Caribbean, by origin, 1970-98.

Sub-region or country	1970-1980						1981-1990						1991-1996						Total					
	Total	Local	IRRI	CIAT	Other	% CIAT	Total	Local	IRRI	CIAT	Other	% CIAT	Total	Local	IRRI	CIAT	Other	% CIAT	Total	Local	IRRI	CIAT	Other	% CIAT
Caribbean	18	16	2	0	0	0	6	3	1	2	0	33	3	0	1	2	0	67	27	19	4	4	0	15
Cuba	3	1	2	0	0	0	5	4	0	0	1	0	6	6	0	0	0	0	14	11	2	0	1	0
Mexico	22	14	8	0	0	0	11	5	2	2	2	18	3	2	0	1	0	33	36	21	10	3	2	8
Central America	8	2	2	4	0	50	20	1	0	18	1	90	18	3	0	15	0	83	46	6	2	37	1	80
Tropical Brazil	4	4	0	0	0	0	30	13	2	11	4	37	23	14	0	7	2	30	57	31	2	18	6	32
Temperate Brazil	11	3	4	4	0	36	12	5	1	4	2	33	14	8	0	6	0	43	37	16	5	14	2	38
Andean countries	17	1	6	9	1	53	23	5	3	13	2	57	22	2	0	17	3	77	62	8	9	39	6	63
Southern Cone	4	3	0	1	0	25	9	6	0	1	2	11	3	2	0	1	0	33	16	11	0	3	2	19
Total	87	44	24	18	1	21	116	42	9	51	14	44	92	37	1	49	5	53	295	123	34	118	20	40

Table 4. Modern semidwarf varieties (MSV) in production and area implicit yield, Latin America and the Caribbean (LAC), 1966-95.

Varieties	Production (1000 t)				Area (ha)				Yield (t ha^{-1})			
	1966	1981	1989	1995	1966	1981	1989	1995	1966	1981	1989	1995
Anaerobic:												
Irrigated	4,328	7,710	11,022	12,518	1,252	1,952	2,475	2,519	3.5	3.9	4.5	5.0
MSV	0	6,110	9,708	12,310	0	1,491	2,097	2,459				
Rainfed	2,026	2,178	2,840	4,273	674	678	816	1,144	3.0	3.2	3.5	3.7
MSV	0	1,162	1,968	3,277	0	341	505	820				
Subtotal	6,354	9,888	13,862	16,792	1,926	2,630	3,291	3,663	3.3	3.8	4.2	4.6
Subtotal MSV	0	7,272	11,676	15,587	0	1,832	2,602	3,279				
Aerobic (Upland):												
Mechanised	2,809	5,070	3,684	2,920	2,812	4,786	3,146	2,123	1.0	1.1	1.2	1.4
MSV	0	350	489	722	0	279	325	381				
Manual	990	788	877	959	1,100	847	904	940	0.9	0.9	1.0	1.0
MSV	0	236	263	288	0	220	255	293				
Subtotal	3,799	5,858	4,561	3,879	3,912	5,633	4,050	3,063	1.0	1.0	1.1	1.3
Subtotal MSV	0	586	752	1,009	0	499	580	674				
Total LAC	10,153	15,746	18,423	20,670	5,838	8,263	7,341	6,726	1.7	1.9	2.5	3.1
Total LAC MSV	0	7,858	12,428	16,596	0	2,331	3,182	3,953				

SOURCE: Estimated from:

Avila Diaz, 1981; CIAT, 1979; 1995; CIAT-IRTP, 1983; Dalrymple, 1986; IRRI, 1995; Muchnik de Rubenstein, 1984; Posada, 1981; Sanint, 1992; Scobie and Posada, 1977; and Valente Moraes, 1977.

While the upstream linkage to IRRI was a valuable component of this improvement, high quality downstream activities at the country level, frequently involving co-operation between public programs of research and extension with private producer organisations, were key to locally relevant adaptive efforts. Through research, extension and training, the new knowledge was used to accelerate and expand the spread of improved germplasm, complementary cultural practices and related institutional and policy developments. Although the private and public sectors have made large investment commitments over the past 30 years, attractive (even unprecedented) returns have been gained.

1.2 Rice consumption

During this century, rice gradually became a staple food for consumers in tropical Latin America. Per capita consumption of white rice rose from 10 kg in the 1920s to about 30 kg in the 1990s. Rice is the most important grain crop for human consumption across tropical LAC, supplying more calories to the diet than wheat, maize, cassava or potatoes. In the rapid process of urbanisation of LAC, where 70% of the population now lives in the cities, rice has displaced from the diet the traditional, bulky and perishable staples such as plantains, cassava and yams.

About half of LAC's population lives below the FAO poverty line, and income is lowest in the tropical parts. For the poor, food purchases account for over 50% of total expenditures of which rice accounts for 15%. With rice prices falling by about 50% in real terms over the period (Table 5), consumers have been the main beneficiaries. Rice is now well established as a "wage good", and it became the most important source of calories and proteins for that 20% of the population with lowest incomes. Figure 1 shows the increasing trend in consumption during the last 15 years in high-level consuming countries such as Ecuador, the Dominican Republic, Cuba, Peru, Brazil and Colombia.

Although the average consumption level is below that of developing countries and of the world, Brazil increased consumption by 6 kg per year reaching the level of 60 kg per capita of paddy rice equivalent to a daily intake of 400 calories.

In Latin America the rice market is mainly internal with open policies over prices. Brazil is the largest producer (55% of total production), consuming 67% and importing 64% of the total rice imports with a total value of over 400 million dollars, mostly supplied by Uruguay and Argentina (Figure 2).

Table 5. International prices of white rice, Bangkok, 5% broken, 1966-95.

Year	US wholesale price index 1995 = 100	Nominal price of white rice, Bangkok 5% broken	Nominal price of paddy rice (White *0.5)	Real price of paddy rice US$ of 1995
1966	27	166	83	310
1967	27	221	110	413
1968	27	205	102	372
1969	28	185	92	324
1970	29	143	71	242
1971	31	130	65	213
1972	32	150	75	235
1973	36	297	148	411
1974	43	541	271	632
1975	47	363	182	387
1976	49	254	127	259
1977	52	272	136	262
1978	56	368	184	328
1979	63	334	167	265
1980	72	434	217	301
1981	79	483	241	307
1982	80	293	147	183
1983	81	277	138	170
1984	83	252	126	152
1985	83	217	109	131
1986	80	210	105	131
1987	82	230	115	140
1988	86	301	151	176
1989	90	320	160	178
1990	93	287	144	154
1991	93	313	156	167
1992	94	287	144	153
1993	95	268	134	140
1994	97	294	147	152
1995	100	353	176	176

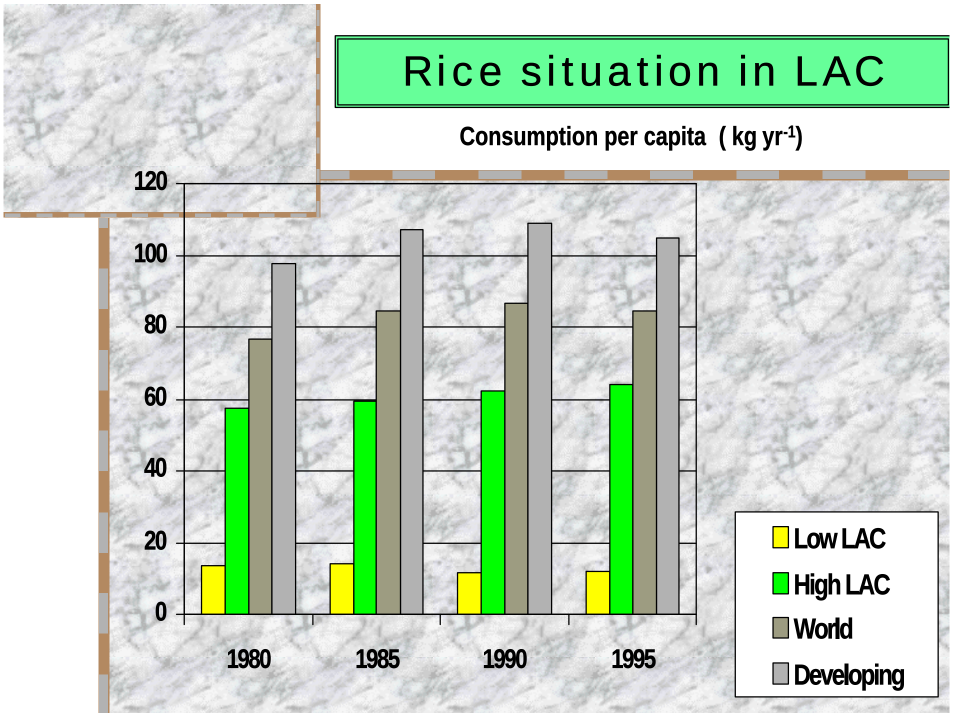

Figure 1. Average rice consumption in low-consuming and high-consuming countries of Latin America and the Caribbean (LAC), in the World and in developing countries. Processed from Food Balance Sheets/FAOSTAT, 1998.

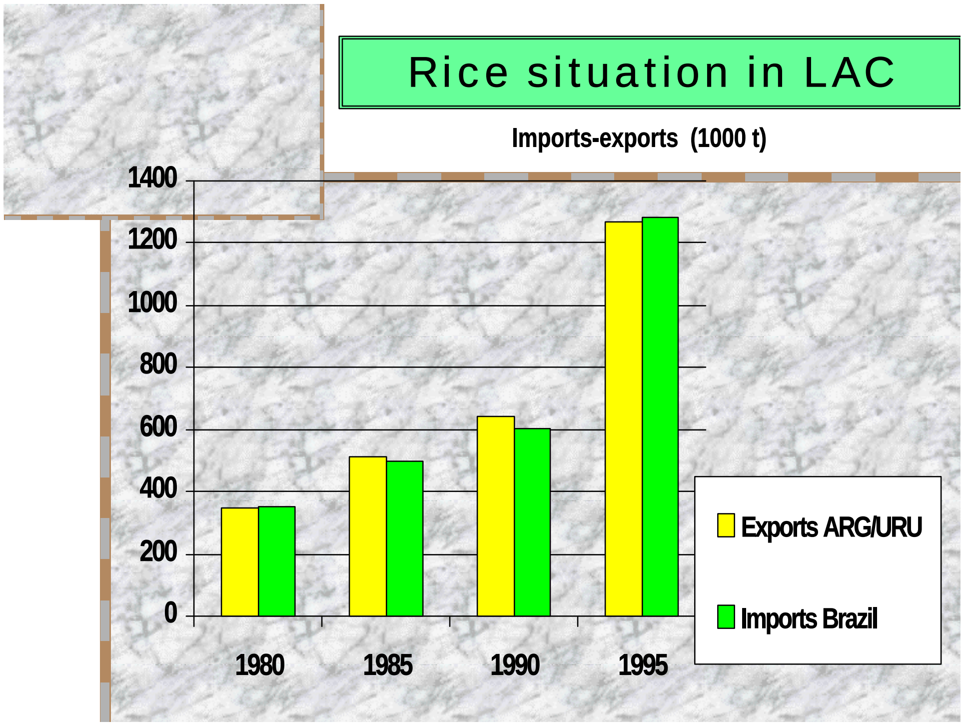

Figure 2. Rice exports from Argentina and Uruguay and Brazil imports, 1980 to 1995. Processed from Food Balance Sheets/FAOSTAT, 1998.

1.3 Stages in rice production, 1966-1997

Latin America produces some 20 million tons of paddy rice which represents about 3.6% of the world rice output in an area of 6.1 million ha (4.1% of the world rice area). By 1995, the dominant rice environments in this continent were wetland rice (54.5% of the area) and upland rice (45.5% of the area). Wetland rice (3.7 million ha) is dominated by irrigated cropping, which occupies two-thirds of the area; the rest is almost entirely cultivated under rainfed, lowland rice. Upland rice (3.0 million ha) is predominantly mechanised (2.1 million ha), while manual rice farming covers almost 1.0 million ha. (Table 4).

1.3.1 Traditional varieties

Before the advent of the new MSVs, rice for most of this century had been a pioneer crop in the vast savannas and in the forest margins of Latin America. Mechanised upland rice predominated in the colonisation of the savannas while manual, traditional rice cropping has been a key component in the forest margins. The traditional and the new tall varieties developed for acid soil conditions proved to be highly efficient in the uptake of the scarce nutrients available in newly opened lands. They constitute the most viable alternative as a first cash crop, until fertilisers and land amendments succeed in improving soil conditions to make them suitable for other crops like maize, cotton and soybeans. Rice has also been important in pasture establishment for acid soils.

1.3.2 Modern semidwarf varieties.

The advent of the new rice technologies associated with the MSVs of the 1960s had a sharp impact on the relative shares of the predominant rice production systems. Different stages can be distinguished.

1.3.2.1 Early adoption, 1966-1981. By 1966, the tall traditional varieties covered the entire rice area (5.8 million ha). The 1970s witnessed a rapid adoption of the new semidwarf varieties for irrigated environments, mainly in the tropical countries. By 1981, the region produced 15.7 million tons, an increase of 50% from 1966 (Table 6). About half of this rice came from MSVs and over 75% of the irrigated rice area was under these new varieties. The new semidwarf rice varieties of the late 1960s made flooded and irrigated rice systems more competitive; higher yields resulted in lower unit costs and lower real rice prices. Upland rice, confronting a lower relative price, but without yield advances, was also displaced by maize, soybeans, cassava, plantains, cotton and other crops as a pioneer crop in the areas of deforestation. The area under manual, traditional upland rice fell from about 1.1 million ha in 1966 to 0.85 million in 1981.

In the savannas, the story was a little different. Brazil produces over 90% of the upland rice in the region. This country made a firm commitment in the 1950s to develop the vast acid savannas (*cerrados*); the decision even included the removal of the nation’s capital from the coast (Rio de Janeiro) to the *cerrados* (Brasilia) in the 1960s. Today, the acid savannas of the *cerrados* produce over 40% of the country’s total grain supply. This aggressive expansion of the Brazilian frontier had a peak during the 1970s and was heavily based on government support. Large, mechanised rice exploitation was favoured by several schemes based on price support, crop insurance, forward contracting by the public sector et cetera. Because of these policies, the rice area in Brazil peaked in 1976 at 6.7 million ha accompanied by a surge in the upland area that reached 6.1 million ha. Over this period, the area of mechanised upland rice rose from 2.8 million ha in 1966 to 4.8 million ha in 1981 (Table 4).

Table 6. Percentage of modern semidwarf varieties (MSV) in production and in area, Latin America and the Caribbean (LAC).

Production system	Percentage in production				Percentage in area			
	1966	1981	1989	1995	1966	1981	1989	1995
Irrigated	0.0	79.3	88.1	98.3	0.0	76.4	84.7	97.6
Rainfed	0.0	53.3	69.3	76.7	0.0	50.3	61.8	71.7
Subtotal wetlands	0.0	73.5	84.2	92.8	0.0	69.7	79.1	89.5
Mechanised upland	0.0	6.9	13.3	24.7	0.0	5.8	10.3	18.0
Traditional upland	0.0	30.0	30.0	30.0	0.0	26.0	28.2	31.2
% MSV in total LAC	0.0	49.9	67.5	80.3	0.0	28.2	43.6	58.8

1.3.2.2. The lost decade: 1981-1989. Throughout the 1980s economic stagnation was the norm in the region. Promotional rice policies were phased out in the late 1970s when the heavy foreign debt and the fiscal burden coupled with rampant inflation rates meant that promoting extensive agriculture became unfeasible. Mechanised upland rice subsidies were virtually eliminated in Brazil by the mid-1980s. The total rice area in LAC decreased from 8.3 million ha in 1981 to 7.3 million ha in 1989, while yields increased from 1.9 to 2.5 t ha^{-1} as the adoption of new varieties continued. In Brazil, a relatively late adopter of MSVs, the new varieties became widely cultivated in the early 1980s. By 1989, regional paddy rice production reached 18.4 million tons. MSVs accounted for two-thirds of rice production and 44% of the rice area. In irrigated rice, 85% of the area was already under MSVs (Table 6).

1.3.2.3 The 1990s. This has been a period of economic recovery, open markets and reduced inflation rates in LAC. Rice production experienced an impressive expansion over the 1990-97 period at an annual rate of 3.8%, the highest of all regions in the world, spurred almost entirely by productivity gains (Table 7). This is explained by the continued release and adoption of high yielding varieties and by a shift to more productive ecosystems. Production from the more stable irrigated and flooded lowland areas is progressively taking over from the low yielding and relatively unstable upland areas of the savannas and forest margins. This release-valve effect created by the new irrigated varieties on the unstable upland systems has substantial implications for the sustainability of rice production in the region.

By 1997, paddy rice production reached 20.6 million tons, or 3.6% of the world rice output. About 98% of the irrigated rice area was under MSVs.

Table 7. Rice: annual rates of growth by continent, 1990-97.

	Asia	Latin America	North America	Africa
Production	1.5	3.8	1.8	3.7
Yield	1.4	3.7	1.0	1.0
Area	0.3	0.1	0.8	2.7

SOURCE: Calculations based on FAOSTAT, 1998.

The most significant growth in irrigated rice production has occurred in temperate South America (southern Brazil, Argentina and Uruguay) where the economic integration of MERCOSUR has opened up new opportunities in production and commercialisation and where the MSVs have been quickly adopted. The rapid expansion in Argentina and Uruguay is also linked to the growing demands from the Brazilian market and the new quality requirements that favour the adoption of "tropicalised" MSVs. Currently, these two countries supply about 1 million tons of white rice to Brazil, or half of its imports. The integration of MERCOSUR implies that the upland rice areas of the *cerrados* will have to face even steeper competition from the irrigated rice systems within the new economic block. Argentina and Uruguay have average rice yields above 6.0 t ha^{-1} and relatively low unit production costs (US\$190 t^{-1}). Consequently, while irrigated rice production in Brazil is regaining ground from its recent setback, upland rice areas continue to lessen. They have been falling since 1976 when they reached over 6.0 million ha. By 1997, the upland rice area in Brazil was registered at about 2.3 million ha.

2. The Regional Rice Project at CIAT: Past and Present Situations

2.1 The History and Evolution of Rice Research at CIAT

Within the Consultative Group on International Agricultural Research (CGIAR), CIAT has regional responsibility for rice research in LAC. While IRRI retains global responsibility, CIAT's Rice Project tackles strategic research in cases where a comparative advantage is apparent through a regional approach. Close collaboration is maintained with IRRI, the West Africa Rice Development Association (WARDA), the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), universities and national and regional programs so that global strategic advances are delivered as soon as possible in forms tailored to the needs of LAC.

The goal of CIAT's Rice Project as stated in the Strategic Plan is to improve the nutritional and economic well-being of rice growers and low income consumers in LAC through sustainable increases in rice production and productivity.

CIAT's Rice Program originated in the 1950s as a collaborative effort between the Colombian Ministry of Agriculture and the Rockefeller Foundation to solve severe outbreaks of the Rice Hoja Blanca Virus (RHBV). This evolved into a comprehensive breeding program within the National Agricultural Institution (ICA), with Rockefeller personnel incorporated into CIAT's Rice Program from its creation in 1967. The objective was to bring the Green Revolution in rice to LAC by developing high-yielding varieties (HYV) and production technologies for irrigated environments.

During the 1970s and 80s, CIATs Rice Program concentrated on: 1) developing improved germplasm for irrigated and rainfed lowland, and for favoured upland agro-ecosystems; 2) developing improved production technology components; and 3) specialised in-service training.

In the late 1960s, the first HYV (IR8) came to LAC. In the 1970s, new irrigated varieties with more acceptable grain quality and tolerance to diseases and insect pests (e.g., the CIAT and ICA [CICA] group) allowed irrigated yields to double from about 2 to 4 t ha^{-1}. By 1992, mean regional irrigated rice yields were 4.6 t ha^{-1}. Between 1966 and 1991, with the release of the new HYV, production of paddy rice in LAC overall went from 9.9 million to 18.4 million tons. This is an annual growth rate of 2.8 %, distributed between 1.7% for yield growth and 1.1 % for annual expansion. CIAT played a key role in this LAC green revolution.

In 1982, CIAT added a station in eastern Colombia, at Santa Rosa near Villavicencio, to better address blast disease and adaptation to acid soil savannas. In 1984, agronomy and socioeconomic capabilities were added to the Rice Program. Because of extensive pesticide use, scientists skilled in integrated pest management (IPM)/ ICM added these subjects to the agenda in 1985. By 1989, the number of core senior staff in the Rice Program reached a maximum of seven. Additionally, two external scientists (one from CIRAD-Département des Cultures Annuelles [CA], France and one from the Japan International Research Centre for Agricultural Sciences [JIRCAS]) were seconded to the Program by their institutes. The CIRAD addition provided the capability to institute a novel breeding approach to broaden genetic diversity, namely population improvement methods such as recurrent selection, which are normally available only to breeders of cross-pollinated crops. The JIRCAS support provided a new capability in plant physiology. Thus, by the end of the 1980s the Rice Program had attained sufficient critical mass to be able to address rice improvement from a holistic, commodity approach.

However, the core complement soon fell to 3.7 scientists. The result was that the commodity-oriented approach of the Program had to be narrowed to a germplasm-only focus. This was supported in the case of savanna upland rice by agronomy and systems research in the savannas Program. However, similar support was not available for irrigated lowland rice.

In the early 1990s, the Rice Program began close collaboration with CIAT's Biotechnology Research Unit and Virology Research Unit. We assessed the potential usefulness of biotechnology, mainly anther culture, molecular markers and DNA fingerprinting, to characterise pathogen diversity, to identify, tag and transfer genes conferring resistance/tolerance to intractable problems of regional importance and to help broaden the genetic base. Research on genetic transformation was added in 1993. Work has been in close collaboration with advanced universities, institutions and private companies of the developed world. The Rockefeller Foundation provided important financial support.

At the end of 1993, CIAT decided not to core-fund irrigated rice breeding. CIAT devoted most of 1994 to mobilising financial support for devolution of the funding, management and implementation of irrigated rice research to a consortium comprising primarily the private sector and the National Agricultural Research Systems (NARS) of LAC. In January 1995, CIAT signed bilateral agreements with private and public sector institutions from Brazil, Colombia and Venezuela and with IRRI, establishing the Fund for Latin America and the Caribbean Irrigated Rice (FLAR). Presently, FLAR has nine country members. It complements activities with CIAT's Rice Project.

CIAT now runs 16 Projects in a matrix approach. The Rice Project, Improved Rice Germplasm for Latin America and the Caribbean, has survived thanks to the support of the Colombian government. Colombia became a CG member in 1995 giving US$2 million per year to CIAT, with 25% allocated to rice research—the Rice Program, now a Rice Project. CIAT matches Colombian funds on a one-to-one basis.

Rice improvement in LAC has also benefited from CIAT's co-ordination, in collaboration with IRRI, of a productive network, the International Network for Genetic Evaluation of Rice (INGER-LAC) formerly called the International Rice Testing Program (IRTP). This network furnishes the primary contact points with countries of the region, making available to them the new techniques and improved or segregating plant materials. Workshops, to enhance skills in genotype selection for local needs, improve the process. The United Nations Development Program (UNDP) funded the network until 1991, and CIAT/IRRI jointly until 1995. FLAR is now running INGER-LAC, which continues to offer free access to anyone in the region. However, the materials included in INGER-LAC are from IRRI, CIAT and national programs in Asia and Latin America that are public in nature. No advanced lines from CIAT are in the new nurseries because the Rice Project concentrates on developing breeding populations carrying new genes for different traits. FLAR develops advanced lines and distributes them among its members.

2.2 Present Rice Research at CIAT

Rice research in LAC has emphasised growth, equity and enhancing the resource base. Rice is particularly important from these standpoints. Technological progress, improved efficiency, marked production increases and important linkages with the rest of the economy have put rice at top priority for agricultural growth policies in most LAC countries. The poor prefer rice because it is cheap, nutritious, easy to prepare, looks appealing and is easy to store and transport. Rice has also been a pioneer crop in Latin America, playing a protagonist role in the agricultural frontier of the lowlands, the savannas and the forest margins. More recently, in collaboration with CIRAD, promising lines for the hillsides have been developed to bring this important food staple into the range of food crop alternatives for poor farmers in this ecosystem. In the 1967-97 period, 80% of rice production growth (at an annual rate of 2.5%) was caused by increased productivity, releasing the pressure on land expansion in the quest for additional food.

Besides outstanding technical innovation, two major "external" reasons explain why rice research has had great impact in the Latin American region: the simplicity of seed-borne technology delivery for a crop that is as simple and inexpensive to multiply as rice; and in LAC, the well-organised commercial rice sector, which quickly adopts new technology. These external factors will continue to give rice research a comparative advantage in achieving future impact.

Several biotic and abiotic constraints affect rice production in LAC. A rough estimate of the value of production lost to major diseases, weeds, soils, climatic factors and physiological constraints that could be addressed through research amounts to about US$880 million per year. Pests and diseases account for about 80% of production losses in both irrigated and upland environments. To deal with these constraints and sustain yields, farmers apply large amounts of toxic agrochemicals. CIAT's Rice Project in the 1990s researches in a framework of activities aimed at achieving four main outputs that would help solve the major constraints in LAC rice production:

Output 1. Enhanced Gene Pools
Output 2. Knowledge of the Physiological Basis for Rice Traits
Output 3. Rice Pests and Genetics of Resistance Characterised
Output 4. Project Priorities and Research Capacity Enhanced

The future of rice research holds exciting challenges and opportunities. It can continue to make significant contributions to environmental goals such as protecting rain forests and reducing agrochemical use, as well as to feeding people. The private sector is progressively involved in funding national and regional rice research through FLAR, thus continuing to be at the forefront of technology development and institutional maturity in LAC countries.

2.2.1 Output 1. Enhanced Gene Pools

New varieties represent a "pooling" of valuable new traits into an adapted genetic background that farmers can use to increase and stabilise yields. By improving production efficiency, these varieties generate cost savings to farmers, much of which are passed on to consumers in the form of lower prices.

Rapid population growth in Asia and Latin America is increasingly pressuring the already strained food-producing resources of these regions. Moreover, mankind’s intensive breeding of crop varieties narrowed down the genetic base in many crops. The relative diversity of the genetic core of LAC irrigated rice has been estimated, using pedigree information, as already reaching its limits in terms of yield potential. This reduced genetic variation renders modern crop varieties more vulnerable to biotic and abiotic stresses. Further yield enhancement requires the design of alternative genetic combinations. Monitoring advances in genetic base diversification may benefit from methodologies more precise than pedigree analysis.

CIAT's major research in rice germplasm development is typically focussing on pre-breeding activities with the aid of molecular markers—testing and adaptation of the new plant types, commercial crosses with wild rices, population improvement and some conventional pedigree breeding work done in collaboration with national rice programs. CIAT's new role in the 1990s is to complement the breeding efforts of NARS and other partners in the region. Promising lines are made available to other NARS through the INGER network and serve as parents for further regional breeding use. We aim to develop high-yielding germplasm adapted to irrigated, rainfed lowland and upland conditions, tolerant to major diseases and insect pests, with good grain quality and early to intermediate growth duration. To ensure good disease pressure, "hot spot" sites (favourable environmental conditions and high pathogen variability) are used for the evaluation and selection of rice breeding lines.

Ongoing plant improvement efforts must be streamlined using a mixture of biotechnological and classical approaches. Genes from wild germplasm are identified and utilised to improve yield and stress resistance. The main aim is to develop and implement a marker-assisted breeding strategy that will lead to developing higher yield varieties and will simultaneously broaden the genetic base of cultivated rice in LAC.

Present research on population development includes the use of the wild species *Oryza rufipogum, O. glaberrima* and *O. barthii* in genetic crosses with improved rice varieties. Transgressive segregation was observed with several lines, having from 5% to 25% higher yield than the commercial variety used in the cross. Data from different crosses suggest that DNA introgressed from the wild rice can contribute positively to yield in elite rice varieties. Research is also conducted on the use of molecular markers in breeding for rice blast resistance. Blast resistance genes in rice varieties exhibiting durable resistance are being tagged and dissected using molecular markers such as RFLP, AFLP, RAPD and microsatellites. Breeding populations analysed include doubled haploid and recombinant inbred lines. Several useful markers have been identified and are being used in marker assisted selection for resistance to rice blast. Our studies have demonstrated that pyramiding of some complementary resistance genes in a common background is effective in controlling blast populations that exhibit great genetic diversity and virulence. Our Rice Project aims to develop rice varieties with more durable and stable blast resistance than in the past.

The Rice Project emphasises the enhancement of populations and has considerably slowed in producing fixed lines for direct release by NARS in the region. Part of the strategy is to develop and enhance gene pools and populations for well-targeted trait(s)that the regional breeding programs can use as sources of potential parents. Recurrent Selection is a suitable breeding method to achieve this goal. In 1992, the CIRAD/CIAT collaborative project on rice improvement introduced, from Brazil and French Guyana, gene pools and populations segregating for a male-sterile recessive gene.

The main highlights of the project have been to:

- understand how the introduced germplasm performs in the upland acid soils of the Colombian savannas;
- maintain the germplasm by harvesting fecundated male-sterile plants;
- identify adapted fertile genotypes for use in breeding programs for fixed lines;
- start recurrent selection by recombining the best selected genotypes in the introduced germplasm;
- create new populations by incorporating the best locally adapted lines of the CIAT Upland Rice Breeding Program into the best adapted, introduced germplasm that provides a good source of male-sterile background;
- send breeding lines to several National Programs for evaluation and seed increase; and
- increase demand for upland rice breeding lines from new partners in LAC.

2.2.1.1. Wetland rice. More efficient rice varieties with higher, more stable, yields are the essence of what occurred in the lowland rice "Green Revolution". New semi-dwarf varieties enabled farmers across LAC's most favoured irrigated rice area to achieve a 45% yield increase from 3.5 t ha^{-1} in 1966 to 5.5 t ha^{-1} in 1997. This stimulated an increase in production efficiency and an expansion of irrigated rice production from 4.3 million tons to 14.5 million tons over that period. Wetland rice production reached 17 million tons by 1997, or over 80% of rice production in LAC.

The ongoing nature of this impact is reflected in the steady releases of new wetland varieties since the start of the Green Revolution. New varietal releases are an important indicator of progress because they usually represent at least one key trait improved while maintaining other gains already achieved. Over the past 25 years 10 new lowland varieties have been released per year on average across LAC. Some new traits are being generated both in Latin America and globally that promise to continue the remarkable record of past impact.

Market-acceptable grain quality is important for LAC rice varieties. Most Latin American rice consumers prefer long, slender, translucent grains that cook dry and loose, and remain soft after cooling. Millers require a high percentage of head rice. We aim to better understand the genetic control of factors affecting grain quality. Demand for alternative uses of rice is increasing, particularly in the US. Research on new uses of rice appears to open an important window of opportunity for the next century in Latin America.

Anther culture (AC) to bridge wide crosses is now a routine and useful tool in breeding in Latin America. Our experience shows that AC can be used to overcome sterility in wide crosses. It also appears to produce more "intermediate" types of recombinants as opposed to the "parental" types that seem to emerge from wide-cross populations when generations are advanced through selfing. Since 1985, CIAT has incorporated AC as a tool to reduce generation time in rice. Research on AC has increased the yield of doubled haploids, making the tool more cost-efficient for breeders. When compared with the traditional pedigree method, AC appears to be economically practical. Several national programs in LAC have started to apply the AC protocol. CIAT is also using AC to fix enhanced traits in backcrossed populations to develop populations for molecular tagging of several genes associated with cold tolerance, disease resistance and tolerance to submergence among others.

2.2.1.2. Upland rice. In the 1980s, upland rice germplasm for the savannas was developed to be much higher-yielding. It is now reaching the farm and promises an important breakthrough. The new upland varieties are shorter, use fertilisers more efficiently, lodge less easily, and have better grain quality than traditional upland varieties.

About 40% of Latin America's 6.7 million hectares of rice is in the freely drained (aerobic-soil) uplands, producing almost 20% of LAC's rice crop. About two-thirds of the total upland area are in the savannas of Brazil where large-scale, mechanised farming predominates. Upland rice is more tolerant of the acid soils of these areas than any other major food crop, so it plays a strategic role in developing sustainable systems there. Traditional upland rice farming accounts for about 5% of the regional production of rice (or about 1 million tons). Yet over 80% of rice farmers in LAC belong to this system. These farmers are poor and their situation constitutes an important niche where rice improvements can significantly improve livelihoods. However, adoption of modern varieties by these groups is relatively low (less than 30%).

Rice is a major staple of forest-margin and hillside smallholders, many of whom live in extreme poverty. The new upland rice germplasm being developed for hillside conditions (with tolerance to midaltitude climatic conditions) promises to add this important cereal into the range of current cropping alternatives, also enhancing their production and nutrition. The new upland rices will help drive the adoption of improved pastures, a leverage effect far beyond the value of the rice crop itself. These "agropastoral systems" could provide the region with a viable alternative to sustainable approaches for settlers in the Amazon forests who have basic food needs to satisfy.

Because breeding for this agroecosystem is fairly new in most LAC countries other than Brazil, much of the effort in this research area goes into developing and strengthening linkages with national and international groups, including planning of joint projects, exchanging germplasm and methodologies, training and collaborative research. CIAT, CIRAD and the Centro Nacional de Pesquisa de Arroz e Feijão (CNPAF), Brazil, are members of the Upland Rice Research Consortium, co-ordinated by IRRI.

2.2.2. Output 2. Knowledge of the physiological basis for rice traits

The main subactivities designed to obtain this output have been the work with IRRI's new plant type, the search for components for more efficient weed control and the study of mechanisms for tolerance to low phosphorus and acid soils.

In 1997, 446 new plant type selections were evaluated at our screening site of Santa Rosa. This promising material constitutes a new source of germplasm that will contribute to broaden the genetic base and should soon contribute to breaking the yield ceiling. The plant architecture was designed as an improvement over the standard irrigated dwarf. Among the reported advantages of this plant are improved initial vigour, strong and thick culms, thick dark green foliage, large and full panicles, high harvest index and low spikelet sterility. We have selected

31 lines for further testing. They were selected for their large panicle size and strong culms and will be included in the germplasm bank and/or distributed to countries.

The work on components for weed control focused on identifying germplasm with allelopathy and anaerobic vigour. The greatest expenditure in pesticides at the regional level (US$218 million or 45% of the total) is on herbicides. IPM strategies involving thresholds, rotation, better water control and seeding practices, and the use of varieties adapted to water seeding with weed-interference properties, could probably halve herbicide use. Weeds are the primary pest of rice throughout LAC. In Colombia and Venezuela, unpublished panel data from producers for 1991 to 1996 show that weed control represents an increasing share of crop production costs and has risen from about 12% to 15%. Chronic annual production losses of 11% are estimated, compared to 7% for diseases and 4% for insects.

Weed scientists report that few new herbicides are coming onto the market because of the high costs of registration caused by environmental concerns.

Although tillage and herbicides will continue to play a major role in the future, cost-effective and environmentally friendly complementary approaches are clearly needed. IRRI, WARDA, CIRAD and CIAT have recently begun research programs on traits of rice to enhance weed control in their agroecosystems. A collaborative effort between CIRAD, CIAT and FLAR with NARS is identifying and characterising the rice weeds in LAC to produce a CD-ROM that will be valuable to extension workers, farmers, researchers and students in the region. The program is based on an existing version (called ADVENTROP) developed by CIRAD for cotton in Africa.

We estimate that rice traits for enhancing weed control could probably reduce weed control costs by 30%. This would more than justify the research investment.

2.2.3. Output 3. Rice pests and genetics of resistance characterised

2.2.3.1. Durable blast resistance. Blast is one of the most intractable fungal pest problems in cereal cultivation. Crop losses annually cost an estimated US$200 million. When resistance is ineffective, farmers use fungicide sprays. This costs the region an estimated US$170 million per year or 35% of total pesticide expenditures. Besides being costly, most of these sprays are hazardous both to the applier and the environment. The use of these chemicals can be cut by over half with durably resistant varieties, lower seeding rates, more efficient use of lower amounts of applied nitrogen fertiliser, the use of silicon fertilisers and fewer but better-timed fungicide applications.

High levels of genetic resistance exist, but are ephemeral. The fungus rapidly overcomes resistance. "Durable" resistance is a concept receiving much theoretical attention, but progress has been difficult and slow. One of the world's most blast-resistant varieties, Oryzica Llanos 5, is a recent product of CIAT's gene-pyramiding approach. Over 10 advanced lines in this region have a similar level of resistance to Oryzica Llanos 5. The CIAT Rice Project has focused on the characterisation of the blast pathogen’s population structure as a means of understanding its population dynamics and interaction with the rice plant. Pathogen population studies using molecular markers and virulence analysis lead to major benefits reducing breeding efforts and costs and have positive implications in the sustainability of rice production.

The molecular technique, MGR-DNA fingerprinting, reveals the genetic structure of blast in a way previously impossible. This technique can act as an "early warning system" to detect the appearance of new genetic lineages of the blast pathogen, and help breeders in identifying resistance genes that are more durable than in the past.

The main advances during 1997 were:

- understanding the dynamics of the blast pathogen in time and pathogen changes leading to resistance breakdown;
- identifying sources of resistance to blast for combining complementary resistance genes;
- developing rice lines (F6) combining complementary blast resistance sources that exclude pathogen population in Colombia; and
- training of national and international scientists in new rice blast research and providing guidance for the development of blast research projects in different Latin American countries.

2.2.3.2. Diversified *Tagosodes*/RHBV resistance. The most hazardous pesticides are the insecticides, which account for an estimated US$95 million, or 20% of the region's total pesticide bill. Control of the *Tagosodes* leafhopper by pesticide application is often self-defeating because it eliminates the predators that could help keep this pest in check. Practical methods for monitoring the predator and pest populations could give farmers the confidence to avoid unnecessary sprays.

The RHBV causes severe recurrent epidemics and is exclusive to the Andean, Central American and Caribbean countries of tropical LAC. It is transmitted by the plant hopper insect *Tagosodes oryzicolus*, which can also cause serious feeding damage even when not viruliferous. Colombian rice farmers were spraying up to 5-6 times to control the RHBV vector and other insect pests in the 1980s. The uncertainty of epidemics induces farmers to spray, even when the problem is not apparent, as "insurance". This costs the region about US$15 million annually.

The RHBV-*Tagosodes* problem provided the original impetus for the creation of the Rockefeller-funded, Rice Improvement Project at ICA (Colombia) in the 1950s. This was the predecessor of CIAT's Rice Program, which started in 1967. Solving the problem was one of the Program’s most notable successes: *Tagosodes* resistance was achieved by 1970 (CICA 4 variety) and was increased in CICA 8 (1978) based on the "Tetep" varietal source.

RHBV resistance based on the "Colombia 1" source was added by 1989 (Oryzica Llanos 4). However, depending on only a single resistance source for each pest for the whole region is risky. New sources have been identified but their genetic control and crossability to adapted LAC materials need to be understood and applied. Transformation with viral genes is also being attempted to create an entirely novel resistance source.

This IPM project has had a broad range of activities. The strategy to enhance germplasm pools with resistance against RHBV and *T. oryzicolus* continues to show improvement as the rate of lines selected for RHBV rose from 27% to 44% in 1997 and more lines were evaluated. Accumulating knowledge of the insect and of the disease's spread is another basic activity taking place in Colombia and is beginning in Venezuela. Other countries will have to follow. The strategy for control complements the varietal approach with the use of agrochemicals and identification of biological control alternatives. Training plays a key role. During 1997, three in-country courses on IPM were held for about 100 participants.

For *Tagosodes* in breeding populations, CIAT, the Instituto de Investigaciones de Arroz (IIA)-Cuba and FLAR developed a new screening method during 1996-97. It tests segregating populations and advanced rice breeding lines for resistance to non-viruliferous *Tagosodes* (resistance to feeding damage per se). Characterised lines and potential parents for crossing are sent to NARS. For resistance to RHBV in breeding populations, the screening activity tests segregating populations and advanced rice breeding lines for RHBV behaviour. These activities are strengthened with the production of transgenic rice with resistance to RHBV. Various RHBV-resistant, transgenic lines of the popular variety, Cica 8, were produced incorporating the nucleoprotein gene of the virus for cross protection. The trait for resistance to RHBV in the transgenic plants is still segregating at the T2 generation. Some plants were nearly immune to the virus, and the best line showing a stable resistance also exhibited good agronomic traits and fertility and high yielding potential. Biosafety field trials with the most resistant lines, combining agronomic traits similar to the original receptor variety, will follow.

2.2.3.3. "*Entorchamiento*" virus. A new production problem known as "crinkling" or "*entorchamiento*" emerged as a serious threat to rice production in Colombia in 1991. This viral disease had been originally described in the Ivory Coast in Africa in 1977. The causal virus belongs to the genus Furovirus and has been identified as rice stripe necrosis. Major research achievements in this area during 1997 were the characterisation of virus physical and chemical properties, the confirmation that *Polymyxa graminis* transmits the virus and the identification of genetic resistance to the virus in both traditional and improved rice varieties.

2.2.4. Output 4. Project priorities and research capacity enhanced

The past 30 years have resulted in strong national programs for rice improvement, high-yielding rice varieties on farmers' fields and networks of germplasm improvement and related information linked, via CIAT, to the leading research resource, IRRI. In the 1990s, CIAT's Rice Project evolved from the breeding and agronomy approach of the past into a strategy focusing on pre-breeding activities that complement the work of the new partnership that emerged in 1995—FLAR.

2.2.4.1. FLAR. Building on this model and stock of capital for sustained progress while assuring its continued dedication to the tasks ahead is the challenge for the rice sector of LAC and is the main purpose of FLAR. The Fund, created in 1995, brings together resources from private and public national organisations. Ten member countries in LAC, plus CIAT, IRRI and CIRAD assumed the responsibility and the control of FLAR's own rice research agenda. FLAR has proven to be a viable alternative by reason of several emerging constraints and opportunities.

First, the maturity and high level of development of national capacities for rice improvement in LAC impose a more important role and responsibility than in the past on national organisations in determining the direction and conduct of future rice improvement efforts.

Second, with large returns currently being enjoyed from rice improvement efforts, those organisations that paid for programs of the past are logically expecting that mechanisms can be devised in the future to capture and turn some of those returns to the long-run maintenance of needed programs.

Third, given the process of globalisation and the "opening of the economies" it is well known that the patterns of demand for new technologies of all kinds will change, the quantities demanded of them will increase and the need to participate in economic blocks will also become more pressing. These changes will especially challenge rice producers and improvement programs.

Fourth, the rapid technological advances in the rest of the world imply that countries of LAC must find ways of keeping in touch with other regions by maintaining strong linkages to foreign sources of technology. The mechanism of the past has proved efficient in avoiding duplicated efforts, using task specialisation, achieving scale economies and providing a fully participatory research apparatus. In this sense, the new effort is being based on the principle of co-operation and efficiency in research while providing stability to the regional research system.

The dissemination of technologies and information has been vital to the achievement of impact in rice. The generation of more new technologies depends on knowing what has already been achieved. The rice sector of LAC is dynamic, and trends must be observed on a continuous basis to guide research and development planning. The creation of FLAR brings stakeholders and technology generators closer together ensuring higher levels of efficiency in information and technology exchange mechanisms, which are a crucial part of the international rice research and development process.

During 1995-97, FLAR raised its working collection from 330 to 477 parents. More than 11,000 samples from member countries were characterised for grain quality. Other important traits of interest worked upon include RHBV, *Tagosodes,* submergence tolerance, and resistance to cold and iron toxicity. Work with CIRAD and Brazil began on transformation of rice to introduce additional genes for tolerance to cold and iron toxicity.

FLAR has organised seven in-country workshops on IPM (in Brazil, Colombia, Costa Rica, Guatemala, Paraguay and Venezuela) and a 1-month breeder course in Colombia. In the first week of March 1997, in Venezuela, the X INGER-LAC Conference and the Fifth World Rice Day co-organised with IRRI and the Fundación Nacional del Arroz (FUNDARROZ) and inaugurated by the President, Dr. Rafael Caldera, were held.

2.2.4.2. Farmers' questionnaires, rice technologies, and costs. The Rice Project has collaborated with FEDEARROZ (Colombia) and FUNDARROZ (Venezuela) in designing and applying farmers questionnaires since 1989. During 1997, data collected from 45 farmers in a 1995 survey in the Tolima (Colombia) region were analysed. The results show a wide spread in practices and in gross margins. The top decile (four farmers) had gross margins of 70% over the direct costs, and the worst four performers showed an average gross margin of 9.5%. As a rule, the most efficient farmers use machinery more intensively and they rely less on labour and on pesticides. Further generalisation is difficult. The average farm size for the top four producers is 8.5 ha and for the bottom four producers, 20.5 ha. Seed density is rather high in all cases (over 200 kg ha^{-1}) because this is a common strategy against weeds.

The main constraints in terms of inefficiencies are found in machinery use (old equipment, frequently rented) and in herbicide use. This points at the high priority these farmers give to weed management because weeds are the result of poor preparation, seed densities, herbicide use and many other crop management aspects. For CIAT, this points out the need to collaborate in identifying germplasm that can compete more with weeds. In 1998, we will analyse sets of data from Venezuela (from the two major growing areas in Guárico and Portuguesa) and new data from Colombia.

3. The Rice Situation in Selected Countries (FAO 1998 Survey)

To overview the present regional situation in rice production, the FAO Regional Office for LAC in early 1998 made a survey of national rice research and development programs of selected producing countries (FAO, 1998). The survey contacted persons and rice programs (Table 8). The survey considered information on production and consumption trends; country policies, strategies and programs for rice production development; information on achievements and constraints affecting rice research; and an assessment of future challenges and opportunities.

The data obtained from the national rice programs (Table 9) confirm the statistical information from FAO sources. A 2% increase in consumption has been reported in Ecuador.

Countries have developed an ample range of policy and strategies for rice production improvement (Table 10). Rice programs are facing the impact of fewer resources being allocated from government sources devoted to applied research and transfer of technology. Co-operatives, farmer associations and the private sector are supporting and developing an increasing and effective technology supply to satisfy rice farmers’ direct demand. The establishment of the FLAR in 1995, with the support of CIAT and IRRI, is playing a central role in promoting programs oriented to competitive technology innovation, seed production and plant protection (IPM). New consortiums of institutions, as in the case of Venezuela, Colombia and Uruguay, are forming a flexible matrix to backup research and transfer of technology programs and to articulate rice sector actors (farmers, research and industry).

Table 8. Persons and rice programs contacted from FAO 1998 survey.

Name	Position	Program or Institute[a]	Country
G. Veitía	Sub-Director	Unión de Complejos Agroindustriales	Cuba
J. E. Deus R.	Dept. Head	Genetic Improvement, Institute of Rice Investigations	Cuba
E. Indarte	National Director	INIA	Uruguay
E. Deambrosi A. Roel R. Mendez		Rice program, INIA-33	Uruguay
A. Acevedo		Seed unit, INIA-33	Uruguay
C. Batello		ACA	Uruguay
E. M. Muñoz	Executive President	FENARROZ and Ministry of Agriculture	Ecuador
J. Kondo L.	Director	INIAP	Mexico
M. Diago R.	Technical Deputy Director	FEDEARROZ	Colombia
S. Maza y Silupu	Director General	Office of Agricultural Information, Ministry of Agriculture and INIA	Peru
A. Ramos N. L. Velasquez M.		FONAIAP	Venezuela
E.P.Guimaraes		CNPAF-EMBRAPA	Brazil
J.F.da Silva Martins	Deputy Research Director	CPACT	Brazil

a. INIA = Instituto Nacional de Investigacíon Agraria; ACA = Asociación de Cultivadores de Arroz; FENARROZ = Federacion Nacional de Arroz; INIAP = Instituto Nacional Autónomo de Investigaciones Agropecuarias; FEDEARROZ = Federación Nacional de Arroceros de Colombia ; FONAIAP = Fondo Nacional de Investigaciones Agropecuarias; CNPAF = Centro Nacional de Pesquisa de Arroz e Feijão; EMBRAPA = Empresa Brasileira de Pesquisa Agropecuaria; and CPACT = Centro de Pesquisa Agropecuaria de Clima Temperado.

A frequently mentioned cause for the sustained yield increase during the last 5 years is the impact of a new wave of improved varieties developed and launched from national rice programs (Table 11). Differing plant types and the expression of disease resistance, abiotic stress tolerance and improved grain quality are the basic features for the new cultivars that are being gradually incorporated into seed production programs. New tools from plant biotechnology, such as protoplast and anther culture, somaclonal variation, mutations and molecular markers and a few attempts at rice transgenesis, are offering new ways and tools to enhance conventional rice breeding in LAC (Zapata and Izquierdo, 1996). The private sector is starting to participate in this process. Farmer co-operatives and medium-sized rice farms are developing applied breeding, testing new approaches for IPM or conducting, with the technical help of free-lance consultants, research on crop management including varietal trials and plant physiology experiments.

The national rice programs reported differing future challenges and opportunities for production development (Table 12). Among the challenges, the further genetic improvement of stress tolerant, disease resistant and high yield varieties is prioritized as well as the development and transfer of transplanting and direct seeding technology including minimum tillage and IPM methods.

Table 9. Information on production, area, yield, consumption, imports and exports from selected producing countries supplied by rice research and developed programs.

Country	Production area (1000 ha)	Yield ($t\ ha^{-1}$)	Production (1000 t)	Consumption ($kg\ yr^{-1}\ capita^{-1}$)	Imports (% national demand or 1000 t)	Exports ($1000\ t\ yr^{-1}$)
Brazil	1080 irrigated	5.0	9180	43	128	-
	2370 highland	1.4				
Colombia	300	4.5	1802	35	185	-
Cuba	150 two seasons	3.5-5.0	350	40	60%	-
Ecuador	300 two seasons	3.8	-	73 (2% yr. increase)	-	200
Mexico	367	-	-	7	370	-
Peru	240	6.0	1459	61	231	12
Uruguay	155 one season	6.7	1034	11	-	643
Venezuela	157 two seasons	-	740	16	105	-

SOURCES: FAO, 1998; FAOSTAT, 1998.

Table 10. Country policy, strategies and programs for rice production development in Latin America and the Caribbean.

Country	Country policy, strategies and programs for rice production development[a]
Brazil	• Competitive situation within MERCOSUR, global market policy favour imports • Reduced subsidies and credit strongly affected farmer economy and production technology • New food alternatives in the basic diet (wheat) affect rice development • Rice farmers direct demand to research centres and research contracts • IRGA (founded in 1940, irrigated rice producers) participating in FLAR since 1995 (founding member)
Colombia	• Insufficient government resources for research programs (ICA and CORPOICA) • To increase CIAT-Colombia program impact (concentrated in Llanos Orientales) • Increased responsibility of FEDEARROZ to backup research and transfer of technology programs • The need to articulate rice sector actors (farmers, research and industry) • FEDEARROZ, founded in 1947, participating in FLAR since 1995 (founding member)
Cuba	• Central planned strategy: Union de Empresas Agroindustriales and MINAGRI • Significant small-scale farms production • Adaptation of improved technology for soil preparation, tillage and harvesting to upgrade costly and obsolete machinery • Yield increase programme (up to 5 t ha^{-1} by year 2000 on 150,000 ha) • Government-run area will be complemented by small-scale farm production (100,000 ha, 20%) through incentives to achieve self-sufficiency • Participation in FLAR since 1996
Ecuador	• Reduction and privatisation of extension services • Strengthening of private enterprises and co-operatives • Programmes oriented to competitive technology innovation, seed production and plant protection services
Mexico	• Governmental programs for strengthening rice production on different locations to compete with imports from USA (NAFTA) and to recover self-sufficiency • Direct support for rice marketing, price regulations • 44% increase in harvested area in 1997 and 24.5% increase in production
Peru	• Record 1997 production • Sustained yield increase due to new varieties, fertilisers and credits • Impact of El Niño effect on 1998 production (1,200,000 t), need for imports because highly important within basic diet • Open market, search for more efficient and competitive rice production • Import tax (5%) to protect national production
Uruguay	• Environmental consideration related to rice production (low input demonstration plots with farmers, pesticide residues monitoring) • Significant increase in area and productivity during last 10 years • Premium price for high quality (long grain) rice • Infrastructure development (irrigation, roads and electricity) • Participation in FLAR since 1998
Venezuela	• Sustained yield increase during last 10 years due to better varieties and crop management caused 93% production increase with only 30% area increase • Support to the rice program of FONAIAP and new varieties • 50% production area with certified seed • Implementation in 1997 of the National Rice Breeding Program with support from FUNDARROZ; FONAIAP; DANAC; UNELLEZ; FUSAGRI; APROSCELLO; UCV, CIAT, and FLAR • FONAIAP project on rice production improvement for the Llanos • Participation in FLAR since 1995 (founding member)

SOURCE: FAO, 1998.

a. Acronyms used: IRGA = Instituto Rio Grande de Arroz; ICA = Instituto Colombiano Agropecuaria; CORPOICA = Corporación Colombiano de Investigación Agropecuaria; FEDEARROZ =Federación Nacional de Arroceros de Colombia; FLAR = Fund for Latin America and the Caribbean Irrigated Rice; MINAGRI = Ministerio de Agricultura; NAFTA = North American Free Trade Agreement; FONAIAP = Fondo Nacional de Investigaciones Agropecuarias; FUNDARROZ = Fundación Nacional de Arroz; DANAC = Fundación para la investigación agricola, DANAC; UNELLEZ = Universidad Experimental de los Llanos Occidentales Ezequel Zamora; FUSAGRI = Fundación Servicio para el Agricultor; APROSCELLO = Asociación de Productores de Semilla Certificada de los Llanos Occidentales; and UCV = Universidad Central de Venezuela.

Table 11. Rice research: achievements and constraints for rice production development in Latin America and the Caribbean.

Country	Research achievements[a]	Constraints
Brazil (tropical)	• New long grain varieties for upland rice: Canastra, Caiapo, Maravilha, Primavera • Crop rotation with dry beans and soybean • Associated sowing rice-pastures (*Barreirao*) improved by CNPAF/EMBRAPA • Hybrid rice breeding and seed program	• Restraints to production incentives and market competition • Weed control: "red rice" • Soil management and plant nutrition • Blast control • To increase yield under irrigation
Colombia	• Two new varieties from FEDEARROZ • FLAR to provide in 1998 the first selected lines to country members • On-farm research on integrated crop management	• Production area reduction due to free market • Per capita consumption decrease
Cuba	• Transplanting rice technology for small-scale farmers • Seed certification program • Integrated pest management (IPM) for weeds • Organic matter incorporation and green manure (*Sesbania rostrata*) • Research program on breeding, crop management, plant protection, irrigation and post-harvest • Six early new varieties (IA CUBA) through conventional breeding, mutation, somaclonal variation (Semidwarf [indica], early season: IA CUBA: 8, 20, 17, 19, 23, 25) • Transgenesis (herbicide resistance) • Only 1 to 5 pesticide applications through IPM, biocontrol and tolerant varieties	• Red rice and other weeds (affects 42 % production area = 40,000 t yr^{-1}) • "Hoja blanca" virus, *Tagosodes*; *Pyricularia* • Water availability for irrigation • 60% national consumption from imports • Soil salinity and degradation on 15,000 ha
Ecuador	• INIAP11 and INIAP12 early maturing varieties, (98% production area) • IPM program (18% cost reduction) • Hybrid rice program (64 hybrids)	• Weak irrigation infrastructure • Need for varietal improvement • Need for tillage and harvesting machinery improvement
Mexico	• New varieties from INIFAP (CotaxtlaA90, Sinaloa A68, Campeche A80, Champoton A80, Palizada A86, Temporalero A95, Sabanero A95, Humaya A92, Culiacan A82, Morelos A92, Apatzingan A88) • Transplanting and direct seeding technology including minimum tillage • Hybrid rice program started in 1996 • New varieties with tolerance to soil and water salinity, drought and to *Magnaporthe*, yield stability, semidwarf and high yield	• Irrigation water availability and quality, high salt concentration • Impact of *Magnaporthe grisea* and of other leaf diseases • Red rice and weed control • Drought

Continued.

Table 11. continued.

Country	Research achievements[a]	Constraints
Peru	• INIA-Viflor (90% production area), Inti; Costa Norte; new high-yielding varieties (INIA: Porvenir 95-resistant to *Perycularia;* Huallaga; Capirona-high quality grain and yield [7 t ha^{-1}, Selva]; Uquihua. New line PNA1562-44 (cold tolerant, semi-late, high quality). New 5 lines with hoja blanca virus resistance	• For Selva conditions: new varieties with horizontal resistance to hoja blanca virus, *Perycularia* and *Helminthosporium* • To increase the use of certified seed • Increase sustainable soil and crop management to promote higher productivity
Uruguay	• El Paso 144 (69%), INIA-Tacuari (23%): high yield-cold tolerance and INIA-Cuaró-(improved) to allow seasonal adaptation • Irrigation management information and transfer of technology to farmers • Integrated crop management (breeding-plant nutrition-irrigation-weeds control-IPM) • Pesticide residues monitoring on water, soil and harvests (LATU) • High degree of adoption of INIA certified seed to supply 100% production area	• Cold during reproductive development affects yield • Prolonged drought affects height of water level
Venezuela	• New varieties by FONAIAP from introduced materials from CGIAR centres and from UNELLEZ and DANAC (Araure 4, Cimarrón, Palmar and FONAIAP 1) • Biotechnology assisted plant breeding activities • Crop management and IPM research results	• To improve sowing, plant density and crop management • High cost of weed control due to poor land levelling, reduced plant density, water management and reduced seed quality seed. • Disease control *(Pyricularia,* hoja blanca virus, *Rhyzoctonia, Sarocladium)*

SOURCE: FAO, 1998.

a. Acronyms used: CNPAF = Centro Nacional de Pesquisa de Arroz e Feijão; EMBRAPA = Empresa Brasileira de Pesquisa Agropecuaria; FEDEARROZ = Federación Nacional de Arroceros de Colombia; FLAR = Fund for Latin America and the Caribbean Irrigated Rice; INIFAP = Instituto Nacional de Investigaciones Forestales y Agropecuarias; LATU = Laboratorio Tecnologico de Uruguay; INIA = Instituto Nacional de Investigación Agraria; FONAIAP = Fondo Nacional de Investigaciones Agropecuarias; CGIAR = Consultative Group on International Agricultural Research; UNELLEZ = Universidad Nacional Experimental de los Llanos Occidentales Ezequel Zamora; and DANAC = Fundación para la investigación agricola, DANAC.

Table 12. Future challenges and opportunities for rice production development in Latin America and the Caribbean.

Country	Future challenges	Opportunities[a]
Brazil (tropical)	• Continue yield increases in the south for irrigated rice, based on new varietal releases and improved crop management • Work on new varieties for irrigated rice in the tropical region of the country • Transfer and adopt the improved *Barreirao* system to rice and other crops	• Good prices for high yield, long grain upland varieties with lower production costs • Integration of sustainable grain cropping systems and pasture implantation • Direct seeding technology-minimum tillage
Colombia	• Reduce production cost by 20% • Recover certified seed market • Adopt conservation tillage management practices • Integrated weed control • Integrated plant nutrition • Training farmers for managerial and decision taking options	• 10% area increase in the medium term • Substitute imports for national production (reduction of production cost) • New lines for animal feed concentrates • Marketing of semi-processed products (add value)
Cuba	• Reduction of imported rice • Stimulation to small farm rice producers	• Strengthen country food security through national sustainable rice production • Integrated pest management (IPM) programmes • Biotechnology impact on improved production through new varieties (salinity tolerance, virus and weed-herbicide resistance) • Irrigation systems improvement
Ecuador	• Improve productivity and production technology • Government declaration of rice as priority sector • Strengthening rice farmer associations to impact policy makers	• Approval of Commerce Law and promotion of exports • High per capita consumption • Low production costs (the lowest)
Mexico	• Develop varieties with resistance to *Magnaporthe grisea* and drought tolerance • Develop the technology and infrastructure for lowland flooded rainfed rice	• Obtain long-day varieties with short grain (*Japonica* type) for export to Japan
Peru	• Seed certification of early varieties • Strengthen research for coastal conditions (65% production)	• Incentives for new production areas at Selva to be "open" • Transfer of technology for Selva conditions with Capirona-INIA variety and for Costa with the new line PNA 1562-44
Uruguay	• Open new sources of irrigation • Increase frequency of rice production within the farming system (livestock)	• Medium term programme for yield and quality increase • Input efficiency and sustainability considering environment
Venezuela	• Strengthen breeding of new early varieties for low input technology, tolerant to high Fe • Reinforce seed certification programs • Pest control and IPM: *Spodoptera*, *Tagosodes*, *Oebalus*, Hoja Blanca Virus, thrips, and other "new" pests • Rodent control (100% losses), bio-control: *Tyto* • Develop sustainable crop management to reduce soil degradation, integrate rotation and green manure, improved soil preparation-tillage, plant density, IPM, weed and disease control, prevention of diseases • Improved post-harvest and storage	• Establish strong link among FLAR, FUNDARROZ and the country's breeding program (FONAIAP) to increase launching of new varieties • Develop a sustainable production system considering agroecological and economic conditions and appropriate technology • Validate and transfer improved practices of post-harvest management

SOURCE: FAO, 1998.

[a] Acronyms used: FLAR = Fund for Latin America and the Caribbean Irrigated Rice; FUNDARROZ = Fundación Nacional de Arroz; and FONAIAP = Fondo Nacional de Investigaciones Agropecuarias.

4. Rice Outlook to the Year 2025

Currently, LAC is a net importer from the rest of the world, with a self-sufficiency index of about 90%. Looking to the future, the region has an enormous potential to supply part of the rapidly growing global rice needs. With world population expanding by about 50% from 1995 to 2025, the demand from rice consumers will have to be supplied from alternative sources. In 1995, LAC held 8.3% of the world population, 12.1% of the arable land, 13.2% of the renewable water supplies, 14.2% of the installed hydroelectric capacity and 27 % of the forests (Winograd *et al*., 1998). This resource endowment potentially gives rice production a comparative advantage. To capitalise on this opportunity, the region must remain competitive. Together with political support, the ability to compete will have to be based on collaborative models at the local and regional level. This will maintain research efficiency and the generation and flow of new technologies to farmers. The successful model developed over the past 30 years is now evolving rapidly in response to a changing world where innovation occurs at an ever-increasing pace.

The world population will reach an estimated 8.3 billion people by the year 2025 (Borlaug, 1997), an increase of about 45% from its 1995 level. From this projection, two scenarios for rice demand can be built: a “ceiling” and a “floor”.

The ceiling assumes that per capita consumption occurs alongside population growth, particularly if the nearly 1 billion destitute living mainly in Asia and Africa improve their diets. Because rice is the staple cereal for these people, their higher demand could imply a growth in total rice demand of nearly 70% above its current level (a per capita increase of 25% added to the population increase of 45%). This means that the world would have to produce an added 400 million tons per year above the current level.

The floor scenario forecasts a reduction in per capita rice consumption associated with urbanised consumption habits, higher incomes and higher protein and vegetable intake, particularly in China. The population growth of 43% would be translated in an expanded rice demand of only 35% (a per capita decline of 8%). This is half of the added needs forecast in the ceiling scenario, but it implies an added rice production of 200 million tons per year above the current production.

The implications are straightforward. Additional production in Asia must happen through added yields, because the frontier is nearly exhausted. “Apparently, in West Asia already some 21 million ha are being cultivated that should not be. Most likely, such lands are either so arid or, because of topography, so vulnerable to erosion that they should be removed from cultivation” (Borlaug, 1997). Therefore, yields will have to increase between 35% and 70%. With the restrictions on water use and availability, much of the increase will have to occur by increasing the varietal potential. Although this is possible in India, Thailand or Indonesia, it is more difficult in China, where average yields are already high (above 5 t ha^{-1}).

Africa still has vast areas that can be brought into production, but the investment in infrastructure (e.g., roads, storage, drying, transportation and port capacity) remains a major limitation and it will take over 25 years to bring these lands into competitive production schemes.

Latin America also has vast potential areas that can be incorporated in cereal production. In the case of rice, however, the savannas of Latin America are more suitable for extensive cattle systems and other crops (soybeans, maize, sugar cane) than for upland rice. This crop can play a role in rotation and pasture establishment, to increase the productivity of the cropping system. Rice yields may increase as new varieties with better adaptation to acid soils conditions are released, but the planted area is likely to continue to decline or at the optimum to stabilise around 2.5 million ha. Irrigated rice has been increasing its productivity; this represents a large handicap in terms of unit costs, given the relatively low and stagnant yields of rice in the acid, relatively poor soils of the savannas. Enormous possibilities exist for increasing irrigated rice areas in the Southern Cone, in tropical Brazil and in other parts of Central and South America. Alongside this expansion, the region will have to maintain the rhythm in productivity increases exhibited in the past, supported by an average of 10 new varieties released every year. During the 1990s, Latin America’s rice production grew at an annual rate of 3.8% with yields expanding at 3.7%. As irrigated areas grew (mainly in the Southern Cone and Guyana), the upland rice areas contracted, for a net result of higher yields without a net increase in area.

Another source of comparative advantage will emerge from the changing nature of labour markets in Asia. The process of urbanisation and industrialisation plus rapid economic growth puts a premium on labour availability and rural salaries. The World Trade Organisation is also pressuring for compulsory social security provisions in every member country. These events imply that Asia will lose its comparative advantage based on cheap labour. As rice production is highly intensive in practices that are labour using (transplanting, harvest and input applications), this change implies higher costs and/or changes in growing and harvesting technologies. Latin America already uses capital intensive technologies, which implies an advantage in know-how for the next century.

The international rice trade has expanded by some 50% from 1992 to its current level of about 22 million tons (white rice equivalent). This is the result of more open trading brought about by the General Agreement on Tariffs and Trade (GATT) agreement of 1992. It is also the result of the growing rice demand, especially in Asia. This dynamic market also opens the door for more specialised trading, where rice quality (large, medium and short grains) becomes important in specific markets.

Another important source of growth in demand should be the industrial use of rice. In the United States, per capita white rice consumption rose from 6 kg in 1980 to 12.5 kg in 1995. Processed products based on rice accounted for most of the increase as its use went from 200,000 tons of white rice in 1980 to almost 800,000 tons by 1995 (Table 13).

Table 13. Rice consumption in the USA, 1969-96 (1000 t)

Year	Uses			
	Direct	Processed	Beer	Total
1969	594	136	210	940
1971	585	157	185	927
1973	603	155	235	993
1975	587	129	210	926
1978	693	168	370	1231
1980	858	203	347	1408
1982	891	151	412	1454
1984	1011	246	319	1576
1986	1120	346	354	1820
1988	1255	391	403	2049
1990	1394	515	498	2407
1994	1575	792	550	2917
1996	1814	754	550	3118

SOURCE: Food Research Associates, 1997

5. Relevant Research Targets for the Year 2020

Latin America has a big opportunity to increase its participation in the global rice market of the next century. However, it will not happen automatically. The region must consolidate its high productive potential based on the comparative advantage that stems from its resources. Rice production must be fostered in stable irrigated areas where the new varieties can express their yield potential. Crop management, and particularly water management, will be key factors in achieving a competitive edge to enter as a supplier of the rapidly growing Asian rice import market. Per capita water availability in LAC is the highest among continents, but this advantage is decreasing (Table 14). Research, adequate policies and increased co-operation are basic to becoming more competitive. Internally, the rice sector must strengthen alliances at all levels of the food chain (e.g., production, seeds, commercialisation, trading and milling). At the regional level consolidating FLAR, the network of collaboration created in 1995, is important. The private sector must increasingly take the lead in all these processes. As most countries now have sources of finance linked to rice production and/or trading (Table 15), this example should be copied by the rest, to secure sufficient resources for rice research, extension and promotion activities in a stable manner.

Table 14. Per capita water availability by continent (1000 m^3).

Country	Year				
	1950	1960	1970	1980	2000
Africa	21	17	13	9.4	5.1
Asia	10	8	6	5.1	3.3
Latin America	105	80	62	48.8	28.3
Europe	6	5	5	4.4	4.1
North America	37	30	25	21.3	17.5

SOURCE: FAO, 1996.

Table 15. Sources of financing from check-off systems, selected countries in Latin America and the Caribbean, 1998.

Country	Source of rice fund	Administering institution
Brazil	17 Brazilian centavos per 50kg bag	Instituto Rio Grande de Arroz (IRGA)
Colombia	0.50% of value of first sale (paddy)	Fondo Nacional de Arroz
Costa Rica	0.25% of value of first sale (paddy)	Oficina del Arroz
Guyana	US$6 per exported ton of white rice	Guyana Rice Development Board (GRDB)
Guatemala	2.00% of value of CIF imports	Arroz Guatemala (ARROZGUA)
Panama	US$0.05 per 50 kg bag	Federacion de Panama de Productores de Arroz (FEDAGPA)
Uruguay	0.50% of value of first sale (paddy)	Instituto Nacional de Investigaciones Agricolas (INIA)
Venezuela	0.30% of value of miller sales	Fundación Nacional de Arroz (FUNDARROZ)
	0.30% of value of loans to farmers	Fundación Nacional de Arroz (FUNDARROZ

SOURCE: Survey of national programs, FLAR, 1998.

To ensure efficiency, profitability and competitiveness in world markets, it is crucial to maintain the rhythm of varietal release which ensures that the yield ceiling can be augmented and that yields can become more stable. Traditional breeding must continue to play a key role in this effort, but new tools and technologies can play an increasing role. A division of labour is emerging that must be enforced because it allows for economies of scale while avoiding duplication of efforts. The international centres are engaged in prebreeding activities: broadening the genetic base (e.g., use of wild rice species, new plant type from IRRI, genetic transformation and mutations), molecular characterisation of the plant and its main pests, and developing and applying new methodologies for breeding (e.g., recurrent selection, hybrid rice and new screening methods). At the national level, the private sector is becoming more involved in research, particularly in breeding. This implies that the public sector should adopt the strategy of completing rather than competing with these efforts. Farmers are in a good position to lead the search for new varieties, but the public sector needs to support these efforts in more sophisticated activities, particularly in the application of novel biotechnology tools. As intellectual property rights are also implemented, some seed and chemical companies will be investing in rice research. Important multinationals (e.g., Monsanto/ Cyanamid and AgrEvo) have a rice research and development program for Latin America. They will be increasingly investing in rice research and participating in strategic alliances with national and international institutions in the region.

Improved crop management practices and new varieties are a must to increase productivity. In most countries, a bigger gap lies between the best and the worst farmers than that between the potential yield of the variety and the one achieved by leading farmers. Often, the latter gap is negligible or non-existent. In Colombia, for example, the gap between average yields of farmers in the upper and the lower quintile within a sample of 46 farmers in the Tolima region during the first semester of 1997 was 56% (7.5 versus 3.3 t ha^{-1}). The strategy in crop management has several levels. At the regional level, the sharing of knowledge needs to be increased through participation in FLAR and other networks. This provides a global vision for locally delivering technologies. At the national and state level, integrated management skills need to be developed through research and demonstration plots. Part of this strategy has to focus on developing the so-called second generation of inputs of the Green Revolution: management and communication skills.

6. Conclusions

Latin America represents about 3.6% of global rice production. The region is largely self-sufficient in rice. This cereal has taken an increasing part in the diet of the population throughout this century to reach a per capita consumption of 30 kg of white rice per year. The region has highly favourable resources for increasing its participation in a rapidly growing world rice market. To seize the opportunity, the process of technology generation and adoption must continue the rhythm of the past 30 years, in which an average of 10 new varieties was released every year. In a more open world, the region must consolidate a regional program of collaboration to avoid duplication of efforts. It must interchange knowledge and experiences and achieve economies of scale in key areas of research, such as germplasm exchange, characterisation of progenitors, development of new, promising varieties and development of ICM skills. The creation of FLAR in 1995 was a step in this direction. In the future the private sector must grow in importance in rice research and development activities. As this sector takes the lead, public institutions (national and international) should seek a complementary role, searching for activities where they may have comparative advantages (e.g., prebreeding and scientific support of the private sector breeding and crop management efforts). The survey of national programs included here clearly shows that new and vibrant alliances are being implemented in most countries and that clearly defined targets exist for the coming years. To consolidate the region as a net supplier of rice for the next century, stable support from policy makers must accompany the efforts in research and development. As water issues become more stringent, it is particularly relevant for the rice sector to take an active lead in aspects dealing with this vital resource.

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