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IRRI TOWARD 2000 AND BEYOND

1989
International Rice Research Institute
P.O. Box 933, 1099 Manila, Philippines

IRRI toward 2000 and beyond

The goal

Improved well-being of present and future generations of rice farmers and consumers, particularly those with low incomes.

The objectives

To generate and disseminate rice-related knowledge and technology of short- and long-term environmental, social, and economic benefit and to help enhance national rice research systems.

The strategy

To increase rice production efficiency and sustainability in all rice-growing environments through interdisciplinary research and to ensure the relevance of IRRI research and the complementarity of international and national research efforts through close collaboration with national programs.

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Foreword

More than 30 years ago, three farsighted men—Drs. F. F. Hill, J. G. Harrar, and R. F. Chandler, representing the Rockefeller and Ford Foundations—joined forces to lay the groundwork for the International Rice Research Institute. The agreement they reached then, with the hospitality, support, and cooperation of the Government of the Philippines, was the start of an international agricultural research network that now spans the world. The base laid in 1960 is today supported by the donor nations and institutions which form the Consultative Group on International Agricultural Research (CGIAR).

IRRI's founders planned an institute with a lifetime of 25 years, with the possibility for extending another 25 years. Today, we are looking toward 2020, some 35 years beyond the first time frame, with IRRI still dedicated to the needs that marked its very early days.

A great deal of strategic planning has been done at IRRI since its establishment. The first decade was devoted to raising the yield potential of irrigated rice to its present levels, predominantly by changing the characteristics of the rice plant. During the 1970s, IRRI's work was extended to include rainfed lowland, deepwater, and upland rice and expanded in the areas of economics and problem soil research. Interdisciplinary work on evaluation and utilization of rice germplasm and its systematic collection and storage were established during this period. IR8, the semidwarf rice that launched the modern changes in the rice world, was followed by varieties with multiple stress resistances, such as IR20, IR24, and IR36. IR36 became the world's most widely grown crop variety. Several countries in Asia approached self-sufficiency in rice.

During IRRI's third decade, we have seen further expansion of the research program, strengthening of national rice research systems, growing concern for women in rice farming, and movement into biotechnology, the frontier of modern agricultural science.

Now we are preparing for IRRI's fourth decade, with IRRI a partner in a growing community of strong national rice research systems. We are taking into account the need to defend the gains made so far in rice production and IRRI's responsibility as a pioneer in making environmental protection and sustainable production systems the cornerstones for planning. We realize that the increase in rice production to the year 2020 needed to meet the needs of a growing global population of rice consumers is about 10 million tons of rice a year. People can continue to be fed only if rice production reaches higher plateaus; that production increase will be attained only through special efforts, in close collaboration with relevant basic and applied research institutions throughout the world.

To achieve the goals outlined in our Strategic Plan, *IRRI toward 2000 and beyond*, rice research must take advantage of all the modern tools of biological and social science and technology. Contemplating the "impossible" has often led to new solutions. We approached the drafting of this strategy by asking the question: "Why not?" Looking well into the future can help IRRI fulfill its role as a research center with awesome responsibilities.

IRRI's Strategic Plan is the product of a joint effort by a very large number of dedicated co-workers. This result of an inspired team approach was reviewed extensively over the last few months. World renowned scientists representing predominantly basic research institutions in 9 countries screened an early draft. A second panel of scientists representing 20 national rice research systems reviewed the draft from the viewpoint of national needs. A third panel of 13 rice experts and 9 representatives of several nongovernmental organizations in our host country went over the draft to judge its relevance to the ultimate user of our research findings, the farmer. They helped to sharpen the focus of our research plans toward the needs of rice farmers and consumers.

We are especially grateful to Mr. John Hardie, of the International Development Research Centre (IDRC), Canada, for spending three months with us to undertake the difficult task of amalgamating the many individual and group papers into this document. To name everyone who helped from within IRRI would result in a very long list of dedicated colleagues who contributed unselfishly to this guidebook for IRRI in the years to come.

This plan documents our beliefs and describes the goals and objectives we feel will help stave off malnutrition and hunger in the 21st century.

IRRI will, without question, remain a center of excellence for rice research and training. We must constantly keep in mind that our concern is for the most disadvantaged part of the world's population: the millions of resource-poor rice farmers and low income rice consumers.

Walter P. Falcon
Chairman of the Board of Trustees

Klaus Lampe
Director General

Preface

Formulating a strategy involves much more than writing a document. The process by which the strategy is developed is itself a major determinant of its value. A strategy cannot be imposed from the top, nor can it be simply the sum of individual views: we have tried to balance the two. This document is the result of an intensive process of internal debate and joint thinking by all IRRI staff and of worldwide external consultation.

A strategy should be a guide for focused programming, but not a straitjacket. The world in which IRRI operates is constantly changing. Our strategy must allow room for us to respond to new opportunities and unexpected problems in a timely manner. The complexity of the issues that IRRI faces makes it impossible to resolve all problems at once. The attempt to do so, however, helps establish priorities.

Changes in the rice world and in IRRI necessitate this detailed examination of the Institute and the directions that it should take.

- The physical and economic characteristics of rice production and consumption—and their long-term prospects—have changed.
- Rice research and scientific advances of potential relevance to rice have reached new levels. The scientific capabilities and physical resources of many national programs are much greater than they were three decades ago.
- The funding system for international rice research has changed. At IRRI's founding, two major donors provided most of the funds. Today, some 20 international centers and dozens of national programs compete for increasingly restricted funds from more than 50 donors.

We face the challenge of defining our place in a changing world and of adapting ourselves to it. We are developing a vision of the future, so that we can better anticipate tomorrow's problems and begin our search for innovative solutions today.

Our strategy addresses the following questions:

- What are the bases for formulating a strategy? Chapter I looks toward our thinking horizon of 2020, at the world of rice and at the world of science and rice research.
- What is IRRI? Chapter II describes IRRI today, its resources, current program structure, strengths, and challenges for the future. It introduces the goal and objectives and the principles and beliefs that guide our actions. It discusses the global rice research services that will need to continue beyond IRRI's lifetime.
- What directions will IRRI take? Chapter III analyzes our broad policies and resource allocation priorities and describes our positions.
- What programs will be implemented? Chapter IV describes the programs and their rationale, goals, and objectives.
- How will we work with others? Chapter V describes the range of possible collaborative approaches.
- How will the strategy be implemented? Chapter VI describes the program management structure and resource allocations and requirements.

CHAPTER I

Toward 2020: IRRI's environment

The world is becoming ever more complicated. Concerns about the availability of food, conservation of resources, and sustainability of the environment are highlighting increasingly complex problems for which solutions are difficult to find. We must try to project the needs of the world for rice far enough into the future to enable us to identify the knowledge and technology that will be required to meet those needs. The research necessary to generate that knowledge must be planned now. We have chosen 2020 as our horizon for projecting needs and problems, in order to target our research strategy for 2000.

Warming trends

Increasing concentrations of "greenhouse" gases in the atmosphere are likely to produce substantial increases in mean global surface air temperatures. One result over time could be a rise in global sea level. The depletion in atmospheric ozone that has been occurring is also expected to continue, with possible hazards to human health and impacts on crop yields, including rice. Rice itself may play a role in the production of greenhouse gases: a significant proportion of atmospheric methane is thought to come from fermentation of organic matter in flooded ricefields. The severity of the dangers posed by these trends is still controversial and the debate is often based on inadequate information. Further scientific enquiry is needed.

Other aspects of life on earth also are warming up. The world already has 5 billion people, with 6 billion predicted by 2000 and 8 billion by 2020. Malthus seems to have been right, so far—that population would grow exponentially. Fortunately, he has, until now, been wrong—that food production would only grow arithmetically. For the most part, food production has kept up with growth

in demand. However, governments and institutions have not yet been able to distribute that food over space and time in such a way that serious hunger and malnutrition can be avoided in some regions of the world.

By 2020, about 55% of the people in today's less developed countries will live in urban areas. By 2000, 23 cities will hold more than 10 million people each (UN 1988); 17 of those cities will be in countries now classified as less developed, 12 of them in Asia. Many of these newly urbanized people may be forced to follow the well-trodden path, from rural poverty to urban poverty and, finally, to destitution. The political heat in many overcrowded areas would rise, and with it the importance of stable and plentiful supplies of food, especially rice and wheat. Clean water will become even more scarce and expensive. Waste disposal could become an insurmountable logistical problem.

The pressures on the natural environment are also increasing. Food production systems have had to be intensified to keep up with increasing populations. People are using more and more nonrenewable, fossil-based energy to grow food. To cook it, they often cut down vegetation faster than it can regenerate. Insidious costs in erosion, soil degradation, and water poilution have been incurred.

This vision of the near future is not alarmist, merely realistic. Much in man's current armory of knowledge and many of the achievements of the past allow optimism. However, in terms of IRRI's part of the picture—rice—we feel that complacency with past achievements is unwarranted. Even maintaining the *status quo* in rice production would be unacceptable, characterized as it is by major disturbing and unresolved questions about the distribution of benefits, food security, and production sustainability. Relaxation of efforts to increase the long-term effectiveness of international rice research would be a serious mistake.

The world of rice: dealing with uncertainty

The risks of looking as far ahead as 30 years are obvious. However, 30 years ago walking on the moon was dreamed of, but was not technologically possible. We must take the risk inherent in crystal ball gazing, of asking "why not?" instead of "why?" Otherwise we face unacceptably high risks that the right answers will not be found in time to avert potential disaster.

Two types of uncertainties should be considered: those related to problems and those related to the potential to solve those problems. For example, problems such as global warming, Third World debt, and disease and insect epidemics affect the production and distribution of rice. The potential to solve such problems, whether through scientific discovery, public policy, or development investment, may change in ways not thought of now. IRRI's research strategies are aimed at minimizing the problems related to adequate rice production on an equitable and sustainable basis by maximizing the potential to solve them.

Even the most optimistic visions of the future recognize the importance of minimizing the risk of staple food shortages. Recent droughts and floods in major food-producing countries are a warning signal. World rice stocks today are equivalent to about 17% of annual consumption—enough for about 2 months. To a degree, other foods can be substituted for rice. But for many consumers, especially the poor, that is not an option: other food stocks are affected by the same national disasters.

People in the rice world

People — the producers and consumers of rice — are IRRI's target beneficiaries and the source of information needed to orient our research programs. They are a source of demand for food, jobs, and income. They also are a management and labor resource employed in a vast range of job opportunities, from the production of inputs for rice cultivation to marketing and processing.

The number of resource-poor farmers and rural landless people in Asia could reach more than 1 billion by 2020. Many are being forced on to highly erodable, marginal land where cultivation cannot be sustained for long. Migration to urban areas in search of a livelihood often leads to other forms of poverty. Either way, a large proportion of the people in Asia can be categorized as low-income rice consumers and/or producers.

As consumers, the amount, the price, the security of supply, and the quality of the rice they eat significantly affect their welfare. As producers, entrepreneurs, and laborers in the input supply and postproduction processes, their welfare is directly related to costs and returns. The majority now and in the future are women and children. Women provide most of the labor in many rice-producing systems and are most directly responsible for the basic well-being of children. There is evidence that, if women are able to earn more, families tend to be smaller. The poorer the household, the more important it is that women have independent access to real income. That income could be derived from rice-based products as well as from rice itself.

The demand for rice

About 80 to 100 million additional people must be fed each year, most of them in the less developed and poorer countries. Rice is the staple food of millions of poor people: half the world's rice production is consumed by those who produce the crop, most of them resource-poor farm households. Virtually all consumers who depend on rice as their primary food live in the less developed countries (Fig. 1). Most of them live in Asia, where 90% of the world's rice is grown and eaten. Asia also has the largest proportion of the world's poor and malnourished people.

Dependence on rice for food energy is much higher in Asia than in other regions (Fig. 2). Rice provides between 35 and 59% of the calories consumed by 2.7 billion people in Asia. In Africa and Latin America, rice provides only 8% of the food energy for not quite 1 billion people.

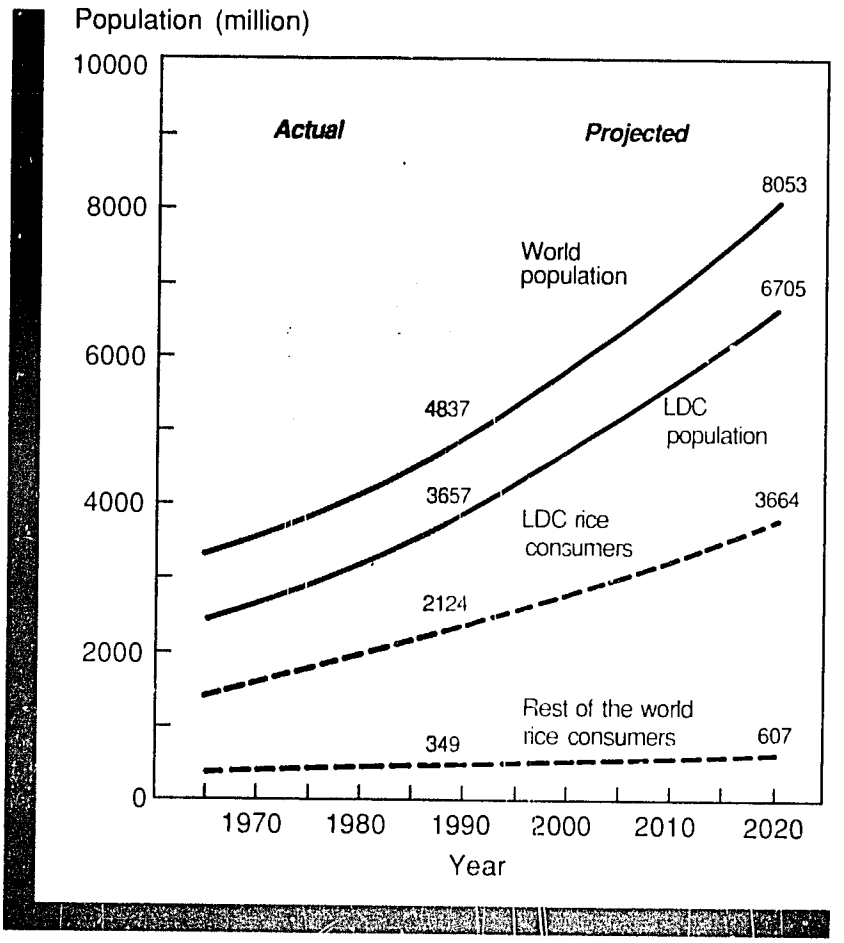


Figure 1. World and less developed countries (LDC) populations and consumers, 1965-2020 (FAO 1980, 1984; UN 1986; IRRI 1988c).

Regardless of the region, most rice-dependent economies have high population growth rates, low rice yields (except for China and Indonesia), and low GNP. Resources for food imports are limited and food aid is only a temporary solution.

When people are poor and hungry, it is not possible to differentiate the relative degrees of need among countries or between the rural and the urban areas. Absolute numbers of such people are what is important in making decisions about allocating scarce research resources. About half the people in South Asia and sub-Saharan Africa receive inadequate calories for an active working life (IBRD 1986). Some 470 million of these malnourished people live in South Asia, 150 million of them live in sub-Saharan Africa.

To meet the projected growth in demand for rice, making allowances for substitutions of other foods for rice in diets as incomes increase, we estimate that the world's annual rough rice production must increase from today's 458 million tons to 556 million tons by 2000 and to 758 million tons by 2020 — a 65% increase

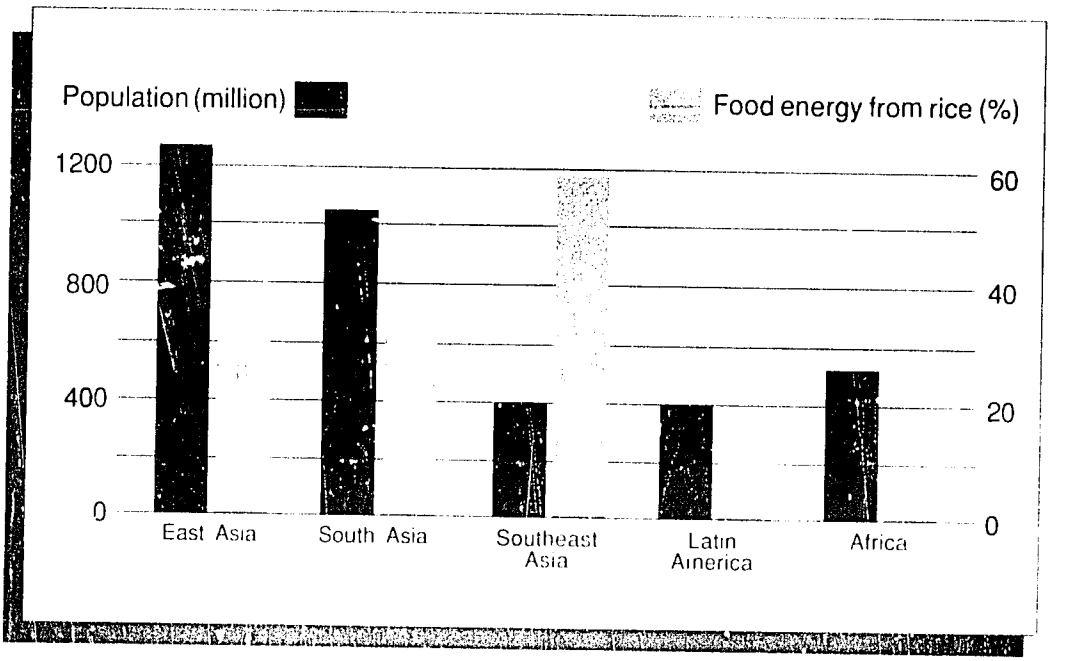


Figure 2. Population and importance of rice in the diet (as % of food energy), by region, 1985 (FAO 1980, 1984; UN 1986).

(1.7%/yr). However, for the leading rice-growing countries of South and Southeast Asia, the needed increase in rice production to 2020 is about 100% (2.1%/yr).

Rice supply

Only about 4% of world rice production is traded on the international market (FAO 1989); most countries rely almost entirely on domestic production to feed their populations. More than 90% of the world's rice is produced in Asia (Fig. 3). But today, Africa has the highest imports relative to domestic production and the highest rate of growth in imports.

The types of ecosystems that must supply the rice are important in planning research. Water regime is the main determinant of the type of rice cultivars and production practices needed. In reality, growing conditions with respect to flooding levels are on a continuous gradient, making precise divisions difficult. Hydrological data are also inadequate. For planning purposes, however, we can consider four broad ecosystems for rice, classified according to type of water regime: irrigated, rainfed lowland, upland, and deepwater and tidal wetland (for more details on characteristics of these ecosystems, see Chapter IV).

The great production gains of the 1960s and 1970s were in the irrigated and favorable rainfed lowland areas, where short-duration, semidwarf varieties could express their high yield potential. Average farm yields of irrigated rice in many countries are still about 3-5 t/ha, but some farmers can obtain twice that.

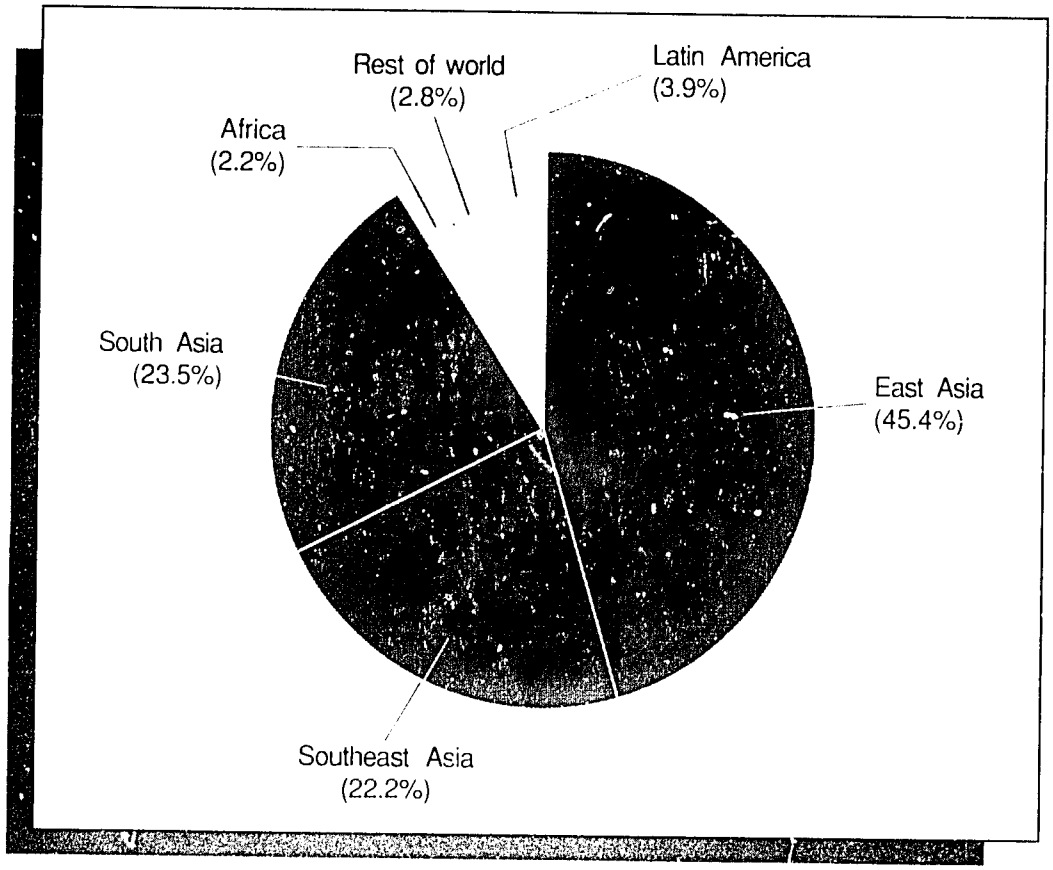


Figure 3. Regional distribution of world rice production (298 million tons milled rice), 1987 (IRRI 1988c).

Many factors will determine the relative contribution of each ecosystem to future rice supplies:

- Production potential and the chances for its enhancement.
- Amount and proportion of research directed to each ecosystem.
- Public and private investment in production and infrastructure.
- Water availability.
- Availability and price of production inputs.
- Rate at which irrigated and rainfed lowland areas can be expanded.
- Loss of land now being farmed.
- Actual and predicted prices of rice and of alternative crops.
- Population growth rates, migration, and urbanization.

Regardless of how these factors combine to affect the relative contribution of each ecosystem, the irrigated areas will continue to dominate production. Irrigated land now comprises about half the total harvested area but contributes more than two-thirds the total production (Table 1).

The less favorable environments (unfavorable rainfed lowland, upland, and deepwater and tidal wetland) produce from 20 to 25% of the world's rice. In the next two decades, they must sustain many millions of farmers and consumers who so far have realized few of the benefits of advanced rice technology.

Table 1. Harvested area, yield, and rough rice production in 37 major rice-producing less developed countries, by ecosystem, 1985 (IRRI 1988a).

Ecosystem	Area		Yield	Production	
	million ha	%	(t/ha)	million t	%
Irrigated	67	49	4.7	313	72
Rainfed lowland	40	29	2.1	84	19
Upland	18	13	1.1	21	5
Deepwater/tidal wetland	13	9	1.5	19	4
Total	138	100	3.2[a]	437	100

[a]Weighted average.

There is potential for expanding the cultivated area of each ecosystem. For example, about 18 million ha of deepwater and tidal wetlands in South and Southeast Asia are not being utilized. Africa and Latin America also have large areas of unused deepwater and tidal wetlands. The contributions of those areas could be enormous if significant constraints such as excess water and salinity and hazards to human health can be overcome. The upland ecosystem also has potential for expanded rice production, although maximizing farm incomes there depends on more diversified farming systems with rice as a component.

Resources and inputs

Some claim that there is enough potential farmland in the world to feed future populations. However, global generalizations are of limited value, at least in rice research planning. The persistent experience—of hungry populations coexisting with adequate and even surplus world food production—means that better distribution systems, even within countries, cannot be relied upon to feed people. Land availability must be considered country by country. The ratio of population to arable land is already high in many regions, particularly in Asia, and agricultural land is being converted for urban development and industrialization.

Land quality is as important as quantity. In many areas, the rate of land degradation is alarming—not least because it increases the pressure to bring less suitable soils under cultivation. A recent assessment by the World Commission on Environment and Development documents a number of examples of land degradation that are pertinent to rice production: "...Without conservation measures, the total area of rainfed cropland in developing countries in Asia, Africa, and Latin America will shrink by 544 million ha over the long term because of soil erosion and degradation..." (WCED 1987). That is more than three times the world's present riceland.

Continuous rice cultivation in some upland areas has been shown to result in significant increases in soil loss. Research in the Philippines measured annual soil losses of 0.073 t/ha in primary forest, 0.146 t/ha in grassland, and 43.5 t/ha in 12-year-old slash-and-burn ricefields (Kellman 1969). Even higher soil losses

have been measured on 9% slopes in northern Thailand (Vergara and Briones 1987). Poorly designed and implemented irrigation systems have caused waterlogging, salinization, and alkalinization (Sadik 1988). As a result, large areas of irrigated land are being abandoned each year.

Water is one of the most critical resources used in cultivating modern rice varieties. The costs of bringing new areas under irrigation and of rehabilitating existing systems are high relative to returns and irrigation investment has slowed. Increasing the efficiency of water use in rice production through appropriate water control and management techniques has become even more important. That must be done in a manner that protects people against waterborne diseases and parasites, particularly in regions where such problems are endemic.

As with land, trends in both the amount and the quality of water available for the next century are disturbing. A view of water as an inexhaustible gift of nature is no longer valid. Research by India's Water Technology Centre points to increasing shortages of water of suitable quality for domestic, industrial, and agricultural uses unless attempts are made to improve the efficiency of its use (Sarma 1986). Although the existence of largely untapped sources of groundwater, especially in the humid tropics, somewhat lessens concerns about the amount of available water, the problems of quality appear to be growing. Canals, ponds, and ricefields in Asia are showing evidence of pesticide pollution. In some areas, pollution levels are affecting fish farming.

Fertilizers, although less problematic than biocides, can have harmful effects if they are used inappropriately. In theory, nitrogen recovery can reach 75% in well-managed cropping systems. But some field studies have measured actual recovery rates of only 20%. Both surface water and groundwater can become polluted because of chemical fertilizers. However, even at high levels of energy input, there is no evidence yet of a decline in the energy input:output ratio (IRRI 1988b). Rice farmers are likely to continue to use increasing amounts of fertilizer to raise production.

The critical feature of this brief overview of the resources used in rice production is the long-term vulnerability of production systems. This is of particular significance in the favorable areas, where production depends on relatively high crop intensity and input levels (water and chemicals). Although the evidence is incomplete, the cumulative effect of stresses on natural resources should not be underestimated. In Thailand, for example, rough rice yields in the Chiang Mai Valley increased from 4 to 7 t/ha per year when farmers changed from traditional to intensive cropping practices. Ten years later, yields have slipped back to the original levels despite continued high inputs of lime and other fertilizers (Gypmantasiri et al 1980). Yields of IR8 and some other improved varieties in IRRI's longterm fertility trials also have declined.

We do not yet understand all the causes. What is certain is that we cannot assume that the production systems upon which the basic food supplies of hundreds of millions of people depend can be sustained for even 10 years without intensive research efforts.

Rice prices

Both current and predicted prices of rice have important implications in setting research priorities. The world market price of rice directly affects national rice production policy decisions, which take into account the profitability of investments in the rice sector, including investment in research. The price trend over time also affects the distribution of the benefits of new technology between producers and consumers.

The small volume of world trade relative to production and the changing structure of the world market make forecasting prices hazardous. The trend line of world market rice prices, expressed in constant dollar terms, shows extreme fluctuations (Fig. 4). Total world rice production has maintained a fairly steady increase, in contrast to the more volatile price. The short-run trends in world rice prices have affected policies on domestic prices and on investments in irrigation and rice research. After the world rice price peaked in 1973-74, investments in irrigation and research rose sharply in the mid-1970s. Now, depressed world rice

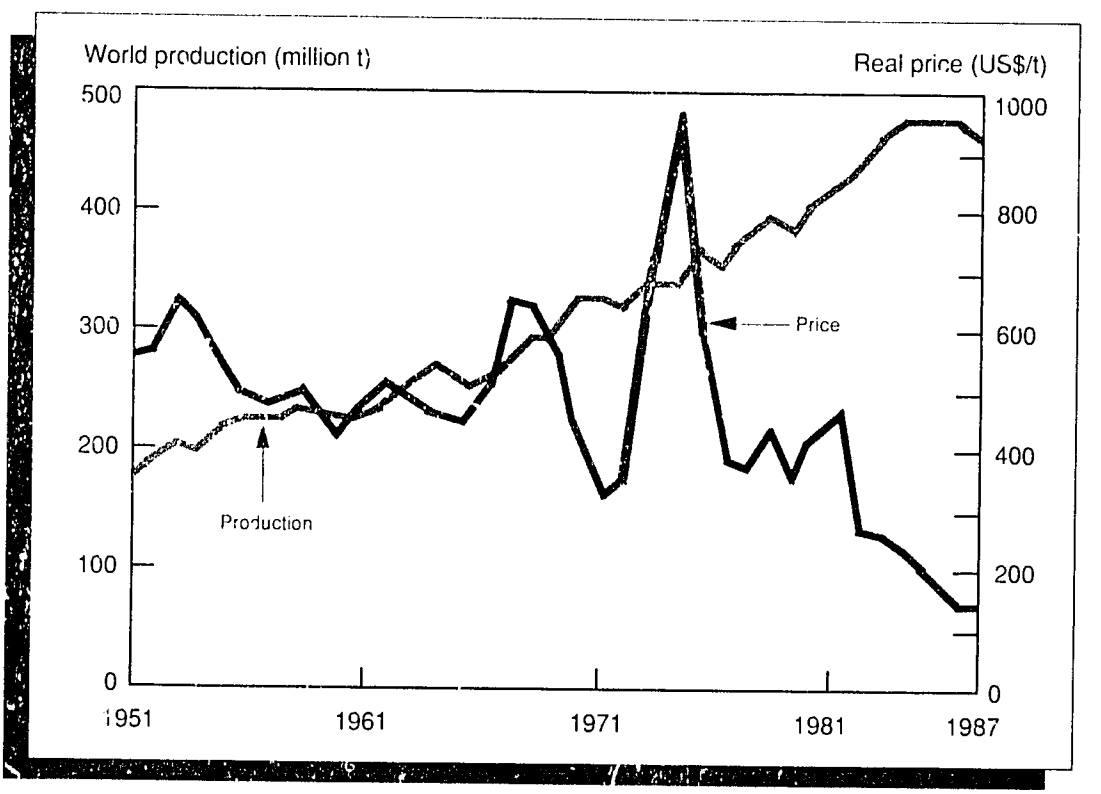


Figure 4. World rice production and price, 1951-87 (IRRI 1988c). Price (f.o.b. Bangkok) is in constant dollars, base year 1985.

prices, heavy debt burdens, and a general slowdown in the economies of many less developed countries have led to dwindling investments in the rice sector.

Projections of future demand for and supply of rice in the year 2000 by FAO (1987), IFPRI (1984), and Barker and Herdt (1985) predict global as well as Asian shortfalls in rice production relative to demand. That will tend to raise world prices. The long-term trend in world rice prices in real terms has remained constant, or even declined slightly, as growth in demand for rice was met by expansion of land area, greater substitution of other cereals for rice, dumping of grain surplus on the world market, and higher yields through modern rice technology. Now, with high population growth and rising costs of irrigation, the scope for further expanding the irrigated rice area in most less developed countries, particularly in Asia, is extremely limited. The costs of producing additional domestic supplies of rice in these countries will rise, leaving them with the choice: to in some way protect local production or to import rice and other cereals. The latter option can lead to reduced welfare for the significant proportions of the population that still depend on the rice economy for their livelihood.

These broad, longer-term considerations of national welfare should also guide public investment decisions in rice research and infrastructure. Basing such decisions only on variable, short-term price shifts in a narrow world market contributes to recurring shortages and oversupply. That fluctuation in turn exacerbates world price instability.

Maintaining the necessary investments to increase productivity in low income rice-dependent countries is not any less essential now than it has been for the last few decades. Unless yield levels can be raised, the costs of protecting national food security and the welfare of rice farmers in less developed countries will increase significantly.

The world of rice research

We anticipate a radically different rice research effort worldwide by 2020. In the arena of international development, it is to be hoped that present terminology that classifies countries as "developing" or "less developed" will be obsolete, that the donor-recipient tone will have given way to terms that define international cooperation for mutual benefit, based on shared resource allocations and shared responsibilities. We expect that many of the major rice-dependent countries will sustain strong, independent rice research programs in specialized areas. For example, despite the comparatively low income per capita of the larger countries (China and India), these countries already occupy positions of considerable scientific strength; their potential contributions to new knowledge by 2020 are hard to conceive in present-day terms.

In contrast, some countries with small populations and very low income levels and resource endowments cannot aspire to the critical mass of scientists and

resources needed for even a scaled-down version of a full-fledged research system. These countries will continue to rely for needed technology on regional cooperation and networking. They also will need to draw upon the research output of advanced national programs and regional and international institutions. The global rice research system of the future will be more extensive, more advanced, and better linked than today's system, which is characterized by heterogeneity.

Rice-dependent countries now devote a wide range of human and financial resources to rice research, with much variation in research direction. Although good quantitative data on the resources devoted to rice research are scarce, a great deal of qualitative information is available at IRRI, much of it not formally recorded. Our collaborative work with national programs is based primarily on this information. The inclusion of quantitative data in a rice-related database being planned now will improve the basis for our planning. That information system also will be part of the IRRI services available to national programs, for their use in planning and for other purposes. The plans of individual countries for human resource development will become increasingly important in evaluating IRRI's potential contributions to the development of particular national research systems.

In terms of the needs of Africa and Latin America, the plans of national programs and of our sister institutes IITA, WARDA, and CIAT are the most relevant. The work of other international centers and agencies, such as ICRAF, ICIPE, IIMI, and IFDC, will be pertinent to concerns about crop and resource management and rice-based farming systems.

Strong links with other advanced laboratories working in rice and rice-related research also will be important. For example, biotechnology tools (such as embryo rescue and haploid breeding) are used routinely in several countries. Protoplast culture, cell fusion, and recombinant DNA technology are possibilities. Linking IRRI with laboratories active in such work will be essential in maintaining the efficiency of IRRI's programs and in optimally exploiting IRRI's comparative advantage.

Scientific frontiers in such areas as ecology, physiology, systems science, and rural sociology also are relevant to IRRI's strategy. Recent advances in computer, satellite, and digital communication technology are revolutionizing the processes of exchanging knowledge and information and of developing skills. Exploitation of that potential is only beginning. New technologies are being developed at least as fast as they can be effectively used.

We believe that the pace and magnitude of all these scientific advances impose upon us two responsibilities. First, we must stay abreast of developments in order to carry out training, collaborative research, communication, and networking as effectively as possible. Second, we must think creatively and apply the kind of ambitious vision that has put man on the moon to generating scientific ideas that could make life better for man on earth.

IRRI's conclusions on the world of rice

Five main issues emerge from this brief analysis of the rice scene and the rice research setting:

- Forecasts of rice supplies do not take into account factors that could adversely affect the long-term security and stability of rice production.
- The factors affecting production apply equally to both unfavorable and favorable rice ecosystems. Future needs of the populations that depend on the unfavorable areas should be addressed more directly.
- In the foreseeable future, the world will continue to rely heavily on the favorable ecosystems, in particular to feed urban consumers. The vulnerability of these systems to degradation demands continued and, in some aspects, increased attention.
- Rapid scientific advances in many fields have potential to help IRRI and its partners find solutions to continuing and emerging problems.
- A wide range of interrelated factors—political, economic, technical, institutional—contribute to increasing and sustaining rice production, protecting the environment, and improving the well-being of farmers.

CHAPTER II

IRRI today and tomorrow

We examine here IRRI's strengths and limitations for our work in the decades ahead, in the context of our goal, objectives, and guiding principles.

Goal and objectives

Goal

Improved well-being of present and future generations of rice farmers and consumers, particularly those with low incomes.

The well-being of low-income people who depend on rice for food can only be assured if, at a minimum, adequate supplies of rice can be made available at prices that are profitable to farmers while they are affordable by consumers. The well-being of rice farmers and laborers—and their families—is measured not only in terms of income, but also in terms of reduced risk and uncertainty, improved nutrition and health, increased opportunities, and decreased drudgery of toiling in hot, humid, and muddy ricefields. IRRI can contribute only to a limited extent to achievement of the goal, which we share with many other institutions and with national governments.

Objectives

To generate and disseminate rice-related knowledge and technology of short- and long-term environmental, social, and economic benefit and to help enhance national rice research systems.

The objectives are complementary. Their achievement and the relevance of our work depend largely on partnership and information exchange with national scientists, extension workers, and policymakers. To this extent, helping to develop national rice research capacity contributes directly to increasing knowledge and developing relevant rice technology.

The objectives are simultaneously end products as far as use of IRRI resources is concerned and intermediate products that must be combined with other factors and knowledge to achieve the goal.

IRRI can only generate knowledge and technology (the objective); it cannot directly generate higher incomes or feed people more adequately (the goal). Our efforts will focus on generating knowledge and technology that have a maximum probability of increasing farm incomes through increased output (quantity and quality) and/or decreased costs. We see the route to improved nutrition as being primarily through improved productivity in rice farming systems. That will increase incomes, provide more adequate nutrition, and sustain adequate supplies of rice over the long term.

The dominant role of women in rice production and consumption in less developed countries is well known. When we speak of benefit in this context, we mean our continuing recognition of the fact that technology has different impacts on different beneficiary groups (e.g., women, children, the elderly). It is inefficient to develop technology without full knowledge of and sensitivity to the ultimate users, as well as of the social and economic systems where it will be applied.

Guiding principles

Concerns

Our main concern is people—the producers and consumers of rice. They form the constituency to which we are ultimately accountable. We belong to the worldwide community committed to alleviating poverty and hunger by applying science to improve the productivity of human, natural, and institutional resources devoted to all aspects of rice production. We commit ourselves to the preservation of rice genetic resources. We value present ricelands, as well as potential new rice areas, as the living base for generations to come and promote their wise use and conservation.

Beneficiaries

Our target beneficiaries are rice farmers and consumers, especially those with low incomes.

Partners

We work worldwide with all research institutions that share our goal, in particular with the national rice research systems of countries where our target beneficiaries live. Rice research has no political boundaries. We search for new solutions to old and emerging problems through personal and institutional efforts and through partnerships with farming communities and other institutions, both public and private.

Role and responsibility

The driving forces of agricultural and economic growth are trained people, effective institutions, improved technology, developed rural infrastructure, and appropriate public policies. IRRI's role as part of an international scientific

community is to contribute worldwide to the improvement of rice technology and to the development of human resources in research and related activities. National governments are responsible for the formulation of appropriate public policies. IRRI's role is to draw attention to the socioeconomic and policy research results that are relevant to the establishment of public policies that will help in achieving the goal.

As we respond to the challenge of the research needed on rice, we strive for excellence through rigorous research and for relevance through cooperation and dialogue with all who can contribute to our goal.

Management

We maintain and work to enhance:

- A research environment conducive to innovation, creativity, and excellence.
- A multicultural, institute-wide social system that encourages all staff members to learn from one another, to share resources and knowledge, and to freely exchange ideas and information.
- Management policies that encourage open communication in all directions and that continue to promote our standards of scientific integrity—which include moral accountability, honesty, commitment, enthusiasm, and cost-consciousness.
- Decentralized management based on visible leadership, interactive problem analysis, and shared responsibility.
- Openness in all our research undertakings.
- Compensation levels based on performance, fully competitive with market standards.

Our guiding principles have resulted in high standards of performance. We state them here as a reminder that they will not be compromised.

IRRI today

Program structure

IRRI now has 13 research departments, 8 global research services, and 5 research support service units (Table 2). Teams of IRRI scientists from various research departments and global research services focus on nine interdisciplinary, mission-oriented research program areas:

- Genetic Evaluation and Utilization
- Control and Management of Rice Pests
- Irrigation Water Management
- Soil and Crop Management
- Climatic Environment and Rice
- Constraints on Rice Yields
- Consequences of New Technology

Table 2. IRRI's departmental organization, 1988.

Research Departments	Global Research Services	Research Support Service Units
Agricultural Economics	Communication and Publications	Analytical Service Laboratories
Agricultural Engineering	International Rice Germplasm Center	Computer Services
Agronomy	International Rice Testing Program	Experimental Farm
Cereal Chemistry	International Network on Soil Fertility and Sustainable Rice Farming	Pesticide Residue Laboratory
Entomology	Library and Documentation Center	Phytotron
Multiple Cropping	Rice Farming Systems Program	
Plant Breeding	Seed Health Unit	
Plant Pathology	Training and Technology Transfer	
Plant Physiology		
Soils		
Soil Microbiology		
Statistics		
Water Management		

- Cropping Systems
- Machinery Development and Testing

The IRRI staff includes 95 internationally recruited scientists (64 core staff, 10 on special projects, and 21 visiting scientists); 87% are stationed at IRRI headquarters—the highest proportion among the international centers that carry out agricultural research within the CGIAR system. Another 2,284 research and support staff are nationally recruited.

Achievements, strengths, and limitations

In terms of human benefit, IRRI's achievements in the irrigated and favorable rainfed lowland rice ecosystems (Dalrymple 1986) have been one of the bright spots of agricultural development in the 20th century. A strategy, however, must be concerned with what we hope to achieve. What has been achieved so far is relevant primarily because it has given us confidence. The confidence that we have in ourselves and that others have in us will be a key factor in helping us meet the research challenges that lie ahead.

A central strategic intention is to build on IRRI's strengths and to draw on the strengths of others. Among our most important comparative advantages are:

- Disciplinary depth. The knowledge and experience that have accumulated within IRRI's highly specialized disciplinary structure are reflected in the more than 90 awards that the Institute has received and in the enthusiasm and creativity that have been maintained for more than a quarter of a century. This gives us the critical mass needed to conduct research that meets the highest standards.
- Technical support. Our scientific staff contributes significantly to IRRI's achievements in rice research. Our technical and general service support is of high quality.
- Political neutrality. We are able to act as a bridge between different political and economic systems and as a reference point for any query concerning rice science from anywhere in the world.
- International character and credibility. We have a strong convening and coordinating capacity and the ability to work with any research institution, anywhere. IRRI has proven itself by tackling issues that cannot be addressed by individual countries.
- International assets. We have been able to collect and conserve more than 83,000 accessions of rice germplasm and more than 125,000 rice publications. These assets will continue to be available internationally.

We are aware, both from our own reflection and from external reviews (CGIAR-TAC 1987, CGIAR 1987), that IRRI is not immune to the process of aging. As in any institution, this can affect not only physical assets, but also the working environment and the research results. We see the following as concerns and challenges:

- Structure. IRRI's present organizational structure makes it difficult to establish problem-focused interdepartmental programs. Wide dispersal of resources over a large number of departments and support units constrains formation of the critical mass of scientific knowledge needed for breakthroughs within an acceptable time span. Overlapping division of labor and expansion of programs in conjunction with centralized decision-making make review of the structure more urgent.
- Facilities. Aging of technical facilities, combined with a period of rapid growth, forces us to replan the use of existing buildings and facilities and to consider rehabilitation. In some cases, research cannot proceed without new facilities.

We will introduce a system of management that helps to minimize administrative procedures. With the new CGIAR planning process, IRRI activities will become less oriented to individual and more oriented to group efforts.

In times of rapid growth, attention can become diverted from effective financial management. IRRI will demonstrate utmost care in the management of

funds, with sharper focus on areas of high priority, comparative advantage, short-term and long-term relevance, and high return. To achieve this, we will intensify dialogue with our collaborating partners and establish systems for participatory planning and monitoring.

We believe that the ability to recognize areas of concern is in itself a sign of strength and a criterion against which a dynamic institution can be evaluated.

A continuing global role

Several important global functions relating to rice research will be needed well into the 21st century. Beyond IRRI's lifetime in its present structure, a politically neutral and commercially disinterested clearinghouse will continue to be needed to lead a global rice knowledge network. Its main functions will be:

- To house the base collection of the world's rice germplasm and to perform the many evaluation, research, preservation, and service functions that this responsibility entails.
- To collect, evaluate, select, and make accessible information on current rice research and development programs, rice and rice-related research results, and global rice research resources (human, financial, physical).
- To retain a response capability that can catalyze the use of these resources (e.g., through specially recruited international teams working on topics of supranational importance).
- To organize and convene conferences, task forces, seminars, and meetings; to facilitate the exchange of information; and to focus the application of knowledge on the resolution of emerging problems.

CHAPTER III

Policies and priorities

Many of the development issues related to rice are interdependent. The range of possible entry points for research is extensive and difficult decisions must be made. We deal here with two aspects of strategic decisionmaking: policies and resource allocation priorities.

Policies

Research relevance

One way to improve research relevance is to develop a more intimate understanding of the environment, production systems, and problems of prospective users and beneficiaries of research results. This implies close contact with farming communities. IRRI faces several constraints in this respect. National programs have the responsibility and the cultural advantage for working with farming communities. IRRI is an international institute and we are moving upstream to conduct more strategic research.

Broad-based research, including research on socioeconomic aspects of rice production, is needed to characterize the rice ecosystems in terms of people and their environment, to improve understanding of the farming systems within which rice is produced, and to refine the definitions of the kinds of technologies that should be developed. This will require close contact with target beneficiaries. For IRRI, this will entail dialogue with all our partners at the national level—government and nongovernment. We will promote participatory research and foster the development of methodologies for farming systems research. In regard to farming systems, activities at IRRI will be on rice and on major interactions with

other systems. We will depend on national programs and other international centers for non-rice component technologies.

Rice consumers also are our target beneficiaries. In our rice-related database, we will include information on the number, location, income status, nutritional needs, and taste preferences of consumers.

In many areas of advanced science, particularly biotechnology and informatics, the private sector plays a leading role. We therefore include private institutions among those with which we will collaborate.

Environmental sustainability

Attention to the impact of high yield-producing technologies on ecological sustainability becomes more urgent as cropping intensifies. Concern for the major components of mankind's life support system—soil, water, flora, fauna, and the atmosphere—is central to IRRI's programming and will translate into specific research activities. Some examples are:

- The impact of rice technologies and associated resource management systems on socioeconomic factors.
- The contribution of rice culture to climatic change.
- The role of irrigation water in waterlogging, salinity, and alkalinity.
- The efficient use of chemical inputs by the rice plant and the effects on the environment and on human health.
- The energy needed for producing, processing, and cooking rice.

Efficiency and equity

IRRI's goal statement is explicitly oriented to both efficiency and equity: it specifies directing effort toward the "well-being of present and future generations of rice farmers and consumers, particularly those with low incomes." While IRRI staff members have always been and will continue to be strongly conscious of our mission, we recognize the limitations on the extent to which an international research institute can, with its resources alone, address equity concerns. We will continue to strive to reduce those limitations.

An efficient research system would allocate resources to return the same marginal social benefits per unit of research input, regardless of where that input was made. It would not be concerned with who received the benefits. However, equity considerations demand that we be concerned with how the benefits from research investments are distributed. Perfect equity (that is, being equally fair to everyone) is an elusive goal. The selection of certain strategic directions will, by definition, leave out those who might have benefited from the directions that are not selected.

The dilemma can be considered on two levels. First, those who are excluded from the initial investment choices. IRRI's concentration on high-yielding rice varieties tailored for the irrigated and favorable rainfed lowland environments has returned limited benefits to those populations dependent on the less favorable

environments. Second, the distribution of benefits among those affected by the initial investment in the favorable environments. At both levels, we find consumers and farmers. Among farmers, we find early and late adopters; small and large farms; and varying degrees of access to credit, water, and fertilizer.

At the first level, it cannot be said that focusing on the favorable rice producing areas has neglected equity concerns. The efficiency gains from IRRI's research have benefited the majority of rice consumers by increasing rice supplies and keeping prices lower than they otherwise would have been. Farmers in the favorable environments also have benefited. In the future, equity concerns of producers and consumers dependent upon the less favorable ecosystems will be explicitly addressed by targeting research to improve production efficiency there as well. The new research program structure will have separate programs for these ecosystems.

An international center has limited ability to address equity concerns at the second level (i.e., the distribution of benefits from the initial research investment choices). Much depends on public policies on prices, agrarian structure, credit, and education; on national research and extension capabilities; and on the character of local farms and farmers. However, by basing research programs on better knowledge of and contact with groups of target users and beneficiaries, the results will be more closely tailored to their needs.

Another dimension of the equity issue can be described as "being fair to future generations." Many current production practices—in all ecosystems—are not sustainable over the long run. This tends to erode the concept of "favorable" and "unfavorable" environments, since human intervention is transforming large portions of the so-called favorable areas into unfavorable ones. By maintaining a strong emphasis on sustainable farming systems in all IRRI work, we will continuously promote the equity concerns of future generations, beyond 2020.

Women and rice

The role of women in rice research and rice farming has both efficiency and equity implications. IRRI has been sensitive to this issue for many years. Some progress has been made in regard to women in IRRI itself, in national rice programs, and as users and beneficiaries of rice technology, but much remains to be done.

We recognize and uphold the principle of affirmative action in the recruitment of all staff at IRRI. We will intensify our efforts to recruit qualified women scientists and administrators. We also aim to increase the proportion of women in IRRI graduate and postdoctoral fellow programs and short-term training programs.

We will continue to promote the integration of women's concerns into all research projects in IRRI and in national programs. Specifically, gender analysis will permit recognition of the contribution of women to rice production, marketing, and consumption; technologies that reduce the burden on women without displacing their income-earning capacity will be developed; and research on rice

processing will aim at conserving the level of essential nutrients. These activities will help us to focus more sharply on the whole family as the ultimate beneficiary of rice research.

Disciplinary strength and interdisciplinary focus

A recurring dilemma in the management of modern science is that, as budgets become tighter and investors in research demand measurable returns, research is subject to increasingly formal planning and more specific management controls. The solutions to many problems require interdisciplinary approaches; that means modifying the traditional disciplinary structure of research.

IRRI, with its mission-oriented mandate (p. xii), must continue to excel in both disciplinary and interdisciplinary research. An overly strong disciplinary bias could diffuse the focus on specific objectives and weaken the balanced integration of efforts needed for effective programming. But too much emphasis on integrating several disciplines carries the risk of diluting the scientific depth needed for real advances in knowledge. IRRI will carefully establish a program structure that permits the pursuit of excellence on both dimensions.

Many of the critical problems in rice production are specific to particular ecosystems. Four main ecosystems will be used to focus research, with the efforts of several disciplines integrated toward solving the problems of each ecosystem. A broad cross-ecosystem research program will promote interdisciplinary work on problems that are not specific to any one ecosystem. The five research programs are:

- Irrigated rice ecosystem.
- Rainfed lowland rice ecosystem.
- Upland rice ecosystem.
- Deepwater and tidal wetland rice ecosystem.
- Cross-ecosystem research.

The rationale for these programs is explained more fully in Chapter IV.

We emphasize that the research programs are intended to facilitate appropriate and necessary interdisciplinary integration. We do not intend to sacrifice intensive and effective contributions of single disciplines when and where needed.

IRRI's policies

Research relevance
We will intensify dialogue with our national partners, in order to improve our understanding of farming systems and the needs of prospective users and beneficiaries of rice research results.

Environmental sustainability
All our programs will be driven by, and many will be specifically directed to addressing, concerns about the effects of rice production systems on the environment.

Efficiency and equity
Our goal statement is explicitly oriented to both efficiency and equity. We will direct research to improve both production efficiency and equitable returns to all rice-dependent groups, particularly those in the less favorable ecosystems.

Women and rice
Affirmative action will be taken in recruitment, in selection of candidates for training, and in research design to address the roles of women in IRRI itself, in national rice programs, and as users and beneficiaries of rice technology.

Disciplinary strength and interdisciplinary focus
A new program structure will facilitate the pursuit of excellence in both disciplinary and interdisciplinary research.

Priorities

As IRRI implements its strategy, we must strike an optimum balance of efforts devoted to several alternatives. None is an either-or choice; effort spent on one often will affect another. The most important are:

- Four rice ecosystems (irrigated, rainfed lowland, upland, deepwater and tidal wetland).
- Three regions (Asia, Africa, Latin America).
- Conducting research and helping to enhance national rice research systems.
- Levels of research (adaptive, applied, strategic, basic).
- Securing previous yield gains and seeking new yield potentials.

At present, IRRI allocates its resources primarily according to departments. A shift to interdisciplinary program budgeting demands a new set of allocation criteria. Achieving optimal resource allocation in terms of our goal and objectives will not be easy. The optimum cannot be derived empirically; many criteria,

particularly those related to equity, are subjective. Striving for the optimum must be a continuous process, with room to adjust as new knowledge becomes available and new opportunities appear.

Hypothetically, an ideal allocation could be approached if it were possible to define all alternatives in advance; to forecast complete social costs and benefits for each, suitably weighted to account for equity concerns; and to select the set that would give the highest net value. However, the range of alternatives for IRRI is too extensive to precisely weight all the factors, even if data were available. A two-stage process has been adopted, based on the goal and the objectives.

First, broad allocations to programs, based on criteria relating to the goal. The criteria include:

- Rice farm households (number and income distribution).
- Rice consumers (number and income distribution).
- Characteristics of current production systems (environmental degradation, vulnerability to pests and diseases, and alternative farm enterprises).
- Country (or regional) characteristics (rice research capability, policy environment, level of development, and extent of extension services and infrastructure).

Second, research projects defined in terms of long-term environmental, social, and economic relevance to each program, appraised according to the following criteria:

- Other institutions' research programs and capabilities.
- Probability of achieving research objectives.
- Costs, minimum scale, and time period required.
- Potential benefits, in terms of value of extra production (quantity and quality) and increased net farm income, environmental enhancement (or at least no degradation), increased stability of production, and reduced risk to farmers.

A two-stage allocation process separates consideration of the probability of contributing to the goal from the probability of achieving particular research objectives. For example, the probability of producing a specified research output could be 1.0. But a research investment would be difficult to justify if the probability that it would contribute to the goal were 0.0. If a country has a policy of subsidizing rice imports while encouraging its farmers to diversify to other crops, there would be little point in targeting research toward solving its rice production problems. Assessing the probability of goal achievement will precede and take priority over the probability of objective achievement.

As we implement IRRI's strategy, the two-stage process will become iterative. Information and analyses accumulated through current research projects will help define future research program allocations.

Not all the criteria listed here will be applicable to all allocation decisions. We have used them selectively and subjectively to arrive at position statements on resource allocation choices. The choices will be refined over time.

Balance among rice ecosystems

Allocation of IRRI's scientific resources among the four main ecosystems is perhaps the most difficult of the choices we face. Few of the many factors that must be considered are static; not all can be objectively quantified. It is risky to oversimplify by focusing only on water regime: rice-growing environments are considerably more diverse than that. Characterization also depends on such factors as climate, soil, topography, and drainage. IRRI's potential contribution to solving all the problems within an ecosystem is limited. Agricultural enterprises other than rice must be considered, particularly for nonirrigated ecosystems. But even in irrigated areas, crop diversification is an issue of growing importance.

A short statement defining precisely what IRRI will do in each ecosystem is not feasible and a categoric allocation of resource shares to each ecosystem has only partial value at this stage. The important first step is to recognize the production constraints, possibilities, and socioeconomic characteristics of each ecosystem, including the fact that those people living in and depending on the less favorable ecosystems have not yet benefited significantly from improved rice technology.

The second step is to put into place a management structure that will facilitate the generation of information, the appraisal of progress against specific criteria, and the monitoring and control of programming. The structure should improve the exchange of information among research programs, since individual scientists may be working simultaneously in several ecosystems.

AREA, YIELD, AND PRODUCTION

A database on key parameters of the rice environments in 37 major rice-producing countries is being developed. Some preliminary information on harvested area, broken down by subregion, is given in Figure 5. It shows the overall dominance of Asia; the importance of irrigated rice in East Asia; and the significance of rainfed lowland, upland, and deepwater rice in East India, Nepal, Bangladesh, and Burma.

It is equally important to consider area, yield, and production in the favorable and unfavorable environments within an ecosystem. Each ecosystem has varying degrees of favorable rice-growing conditions; those must be estimated on a country-by-country basis. For example, IRRI research on the South and Southeast Asian upland ecosystem shows that, in the aggregate, 42% of upland rice is grown in fertile soils, more than a third of that area has a long growing season (Fig. 6).

Much better information is needed on the characteristics, production constraints, and research opportunities within each ecosystem. Refining the database is part of the strategy itself; that will minimize the degree to which allocation decisions are based on subjective judgments.

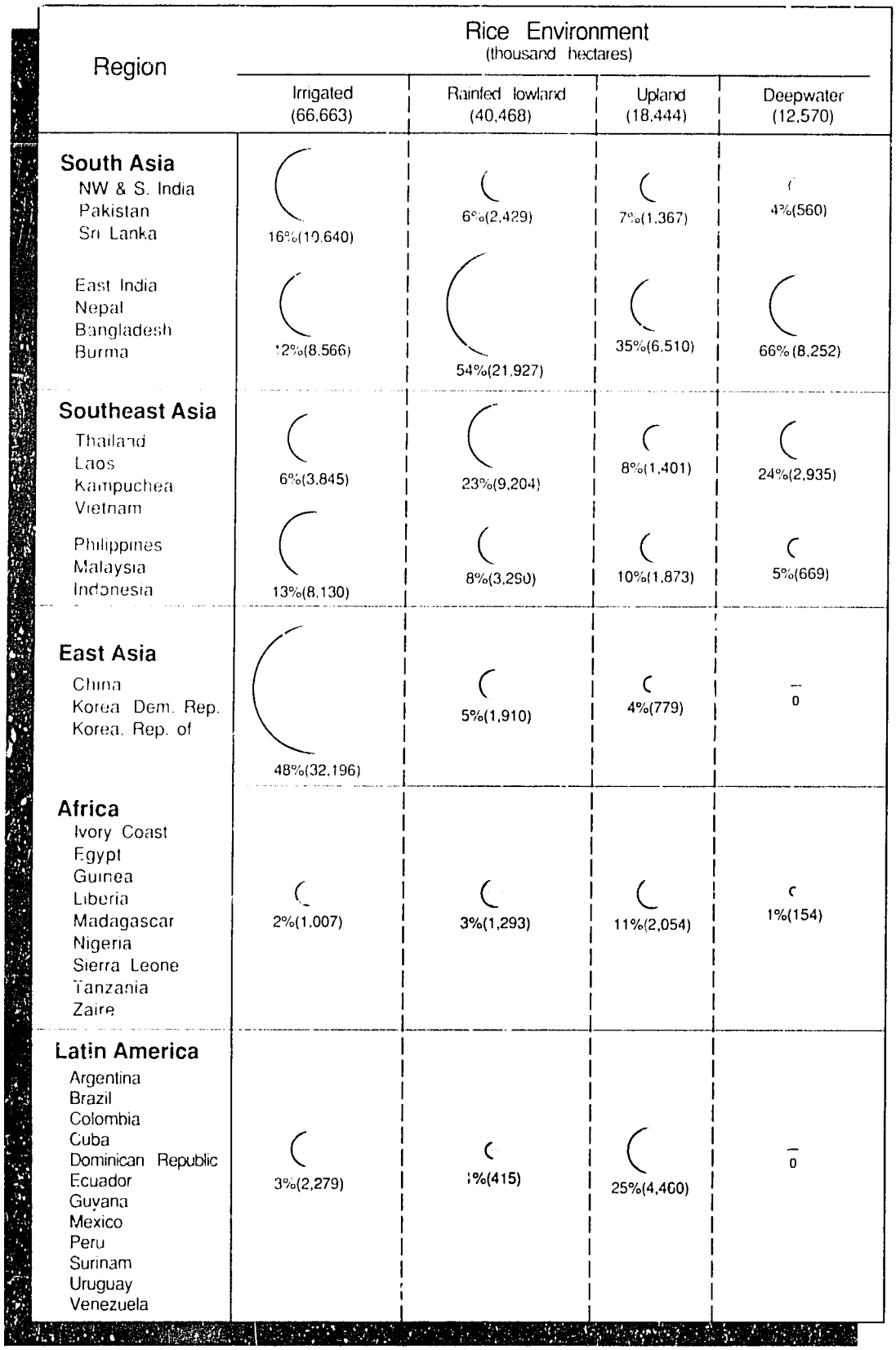


Figure 5. Harvested rice area in four rice environments in 37 rice-producing less-developed countries, by subregion, 1985 (IRRI 1988a). Rainfed lowland includes mangrove swamp areas in Africa. Circle sizes are relative to total rice hectarage, percentages are proportion within each environment

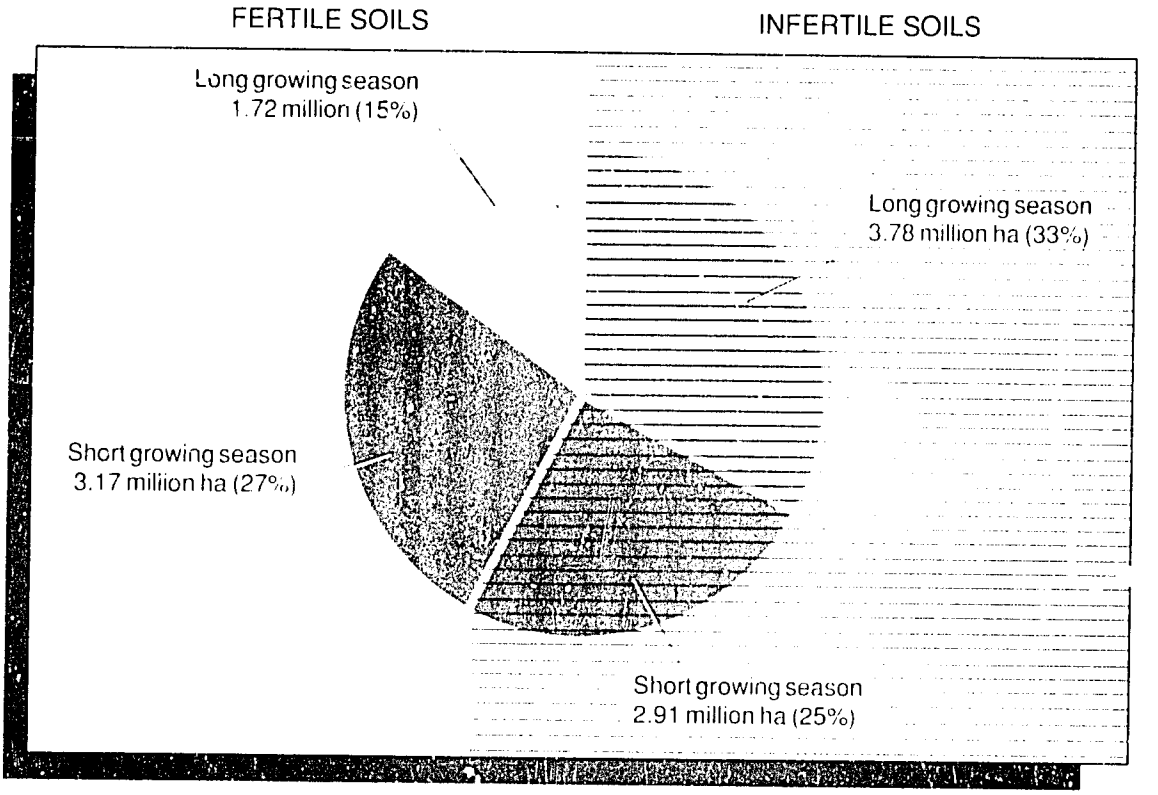


Figure 6. Upland rice area in South and Southeast Asia, classified by growing season and soil fertility (IRRI, unpubl.).

RICE FARM HOUSEHOLDS AND CONSUMERS

Rice farmers depend on their crop for food and for cash income. Nonfarming rice consumers, mostly in urban areas, depend to varying degrees on each ecosystem for their food supply.

Because the four ecosystems are found in varying proportions, not only within a country but even within an individual farm, data on the number of rice producers in each ecosystem are not reliable. The number of consumers who depend on the production from an ecosystem is easier to estimate. A good indication is current production levels: irrigated, 72%; rainfed lowland, 19%; upland, 5%; and deepwater and tidal wetland, 4%. This estimate can be refined by considering the degree of importance of rice in the diets of each country.

IRRI WITHIN THE GLOBAL RESEARCH SYSTEM

Taking into consideration the research programs and capabilities of other institutions, particularly those of national programs and sister IARCs, allows us to identify gaps and to decide where IRRI has a comparative advantage in filling them. For example, WARDA, IITA, and CIAT plan to continue, to a certain

degree, their programs in rainfed lowland and upland areas of West Africa and Latin America. Those areas constitute 74% of the planted area in West Africa and 68% in Latin America. We expect substantial expansion of rice in these ecosystems over the next two decades.

Also, more than half the production of irrigated rice comes from China and Korea. The strengths of those national programs mean that IRRI will not need to give as much weight to the irrigated ecosystem as is implied by harvested area, production level, or yield potential.

At the same time, IRRI must keep abreast of the research results generated by strong national programs and help make them available to other countries and centers.

CHARACTERISTICS OF PRODUCTION SYSTEMS

Environmental degradation tends to be most serious in the irrigated and upland ecosystems. The vulnerability of intensively farmed favorable environments (described in Chapter I) cannot be overemphasized, given the number of consumers who depend on those areas. Opportunities for alternative enterprises are least in deepwater and tidal wetland and greatest in upland.

POTENTIAL PRODUCTION BENEFITS

IRRI scientists have projected the expected benefits from research on the four ecosystems in South and Southeast Asia to 2000. The added value of rough rice production from research was distributed as irrigated 57%, rainfed lowland 29%, upland 4%, and deepwater and tidal wetland 10% (IRRI 1987). These data clearly indicate that, if only efficiency criteria are considered, irrigated rice should continue to receive priority.

IRRI'S POSITION ON ECOSYSTEM BALANCE

Over the long term, IRRI will give relatively less weight to the favorable areas. Although many of the quantitative criteria (area, production, dependent consumers, efficiency) suggest concentrating research efforts on the irrigated and favorable rainfed ecosystems, many national programs are strong in these areas and are assuming more and more research responsibility. IRRI will intensify its exploration of opportunities for scientific advances applicable to the problems of the less favorable ecosystems, taking into account such factors as the potential for production of rice vs other crops, the numbers of dependent farmers and consumers, and the research activities of other institutions. The visibility given the ecosystems as research programs will allow us to target IRRI research and to monitor the results of our efforts.

Balance among world regions

IRRI's original mandate specified research "...for the people of Asia and other major rice-growing areas...." and training of promising young scientists "primarily from South and Southeast Asia...." In 1982, the training scope was reworded to match that for research, confirming our global mandate for both (p. xii).

RICE PRODUCTION AND DEMAND

In terms of current production, neither Africa nor Latin America could be described as "major rice-growing areas of the world." Asia generates 91.1% of the world's rice production (298 million tons of milled rice in 1987); Africa produces 2.2% and Latin America, 3.9% (Fig. 3). Egypt and Madagascar account for 48% of the production in Africa; Brazil and Colombia 46% of that in Latin America.

In terms of per-capita consumption, Asia is also significantly more important than the other two regions. Most Asian countries consume an average 100-150 kg milled rice/person per year (except for countries with large wheat-consuming populations, such as Pakistan [23 kg/person] and India [64 kg/person]). In Africa and Latin America, consumption is less than 50 kg/person per year. Only Guyana, Liberia, and Madagascar exceed 100 kg/person.

Potential for production and consumption also must be considered—particularly in Africa, where it is essential to explore every option for increasing secure food supplies. The main indicators of potential—growth rates in consumption and in imports—are increasing most rapidly there (e.g., 25% of world rice shipments go to Africa). Rice imports in some countries, such as in Nigeria, would be higher if import barriers were removed. However, most imports to African countries are substantially subsidized, in many different ways.

NATIONAL PROGRAMS

Human resources devoted to rice research are spread thinly in sub-Saharan Africa. A qualitative assessment by IRRI indicates that the stronger programs are found primarily in West Africa, particularly in Nigeria and the Ivory Coast. The proportion of IRRI resources directed toward Africa should be considered in the context of current major shifts of international aid efforts to human resource development there, exemplified by such initiatives as the Special Program for African Agricultural Research (SPAAR).

In Latin America and the Caribbean, most countries do not have adequate trained personnel nor financial support and the distribution of national rice research capacity in the region is highly skewed. The more advanced rice research programs are found in Brazil, Colombia, and Cuba.

IARCs AND OTHER INTERNATIONAL AGENCIES

WARDA recently formulated its strategy to 2000. That institute expects to collaborate with IRRI in varietal testing in the Sahel and humid zone irrigated

systems, in developing a Sahel-based breeding program, and in coordinating IRTP-West Africa.

IITA has worked on varietal improvement of irrigated and upland rice, with some recent attention to rainfed lowland rice. Much of its crop management work has focused on West Africa.

IRAT's programs, mostly in Francophone countries, are concerned with varietal improvement and crop management, primarily for irrigated and upland rice. IRAT also has contributed to the establishment of certified seed production in some countries. Some IRAT upland lines are resistant to blast disease.

In Latin America and the Caribbean, we collaborate with the national programs primarily through IRTP, implemented jointly with CIAT. Some useful genetic material has been identified. For irrigated rice, CIAT has actively developed and promoted improved germplasm and such farming practices as weed control, water management, pest management, and harvest technology.

OPPORTUNITIES

There is scope for increased rice production in many areas of East, Central, and Southern Africa where rainfall, solar radiation, and temperature regimes are conducive to rice production. IRRI rice-weather trials in Kenya show that with irrigation, yields of almost 10 t/ha are possible. An average increase of 0.5 t/ha in rainfed lowland yields in Tanzania would produce an additional 100,000 tons of rough rice—more than what is currently imported. Pests specific to Africa, such as yellow mottle virus, are still insignificant there.

There also is potential for an effective contribution to the needs of particular countries in Latin America. For example, some Brazilian upland areas have problems common to those in parts of Asia and some Asian breeding lines selected for blast resistance perform well in Brazil. At the same time, some Brazilian varieties and lines perform well in Asia.

IRRI'S POSITION ON REGIONAL BALANCE

IRRI will continue to focus primarily on Asia. But fulfillment of our worldwide responsibilities will include all regions. IRRI's research role in Africa and Latin America is limited by area and production and by the presence of IARCs and other research institutions. Those limitations are mitigated somewhat by production potential, imports, and rates of growth in demand. IRRI's help in building national programs in Africa will depend on additional donor investments. We will be selective in accepting research opportunities and obligations in East, Central, and Southern Africa and in parts of Latin America, such as in the upland ecosystem, taking into consideration the activities of other IARCs, wide regional and/or ecosystem applicability, and our own comparative advantage.

Conducting research and enhancing national programs

The effectiveness of IRRI research is enhanced by strong national rice research systems. Although building national research capacity is one of IRRI's main objectives, it is as much a means to an end as an end in itself. To a certain extent, the choice is not between clear alternatives: some capacity-strengthening activities involve research and some research activities build national capacity.

In theory, IRRI could allocate all of its resources to research or all to helping strengthen national programs. The criteria for deciding on the balance are:

- The strength of national rice research capability.
- The activities of countries and donor agencies in research and in human resource development.
- The relative contribution of each objective to achieving IRRI's goal.
- The degree to which research and training are complementary rather than competitive.

Many countries still have insufficient research systems. At the same time, IRRI has a wide range of research choices to make. We must be highly selective in meeting both objectives.

IRRI'S POSITION ON RESEARCH AND STRENGTHENING NATIONAL PROGRAMS

We will maintain our commitment to contribute to the strengthening of national research capability. The emphasis will continue to shift to stronger collaboration with national programs. In other words, we will work toward the day when the more traditional training courses are no longer part of our activities. Over the long term, we expect to increase the proportion of our resources devoted to research and to sharing knowledge with all our partners, in a mutually supportive global rice research system.

Balance among levels of research

The CGIAR envisages a continuum of research levels, from adaptive through basic research. Two characteristics distinguish research levels: the extent to which the research can be associated with a specific, real-world problem and the extent to which time and other resources necessary to conduct the research can be specified. The resources needed for adaptive research, including time, are the easiest to quantify. Basic research lies at the opposite end of the spectrum, with exploratory work that attempts to explain natural phenomena.

Three main criteria will determine our choices among the different research levels:

- The level of development of national rice research systems.
- The rice research programs of sister IARCs and advanced laboratories.
- Our comparative advantage.

IRRI's POSITION ON RESEARCH LEVEL

Given that IRRI is oriented to rice problems, we will not conduct basic research as such. We will strengthen our scientific base and increase our communication and collaboration with advanced institutions doing basic research, to enable us to use results from the cutting edge of science. As more national programs develop the capacity to conduct adaptive and applied research, we will increase the proportion of our resources devoted to strategic research. At all research levels, we will collaborate with national programs to ensure the complementarity of our respective research efforts.

Securing yield gains and seeking new yield potentials

A conservative estimate of the average farm yield advantage of modern rices is 0.6 t/ha (Anderson et al 1988). However, this yield gain risks being eroded by pests, diseases, and soil and water problems. A crop management regime in which the quantity and quality of soil and water resources are constant over time would allow sustained production without mining, or depleting, the environment. Even in such favorable circumstances, new pests or diseases could still reduce yield levels.

Research to secure yield gains, therefore, must address two sets of problems: those of intensive rice cropping that tend to degrade and deplete soil and water resources and those caused by the appearance of new biotypes or strains of pests and diseases.

Too much concentration on securing yield gains would risk our ability to meet projected demand for rice. It also would tend to reduce the research resources available to raise yields, especially in the less favorable ecosystems where yield gains have not yet been significant. Too much emphasis on seeking new yield potential might reduce our preparedness to react to a rapid erosion in current yields, such as through an unanticipated pest epidemic. The risks of this occurring, and the potential production loss, are higher in the favorable ecosystems upon which most consumers depend.

The distinction between the two research targets may be more apparent than real. A shift upstream in IRRI's research is expected to result in knowledge that benefits both targets.

IRRI's POSITION ON SECURING GAINS AND SEEKING POTENTIALS

Given their strategic importance, we believe that research should be directed toward ensuring the long-term security of increased rice supplies from the irrigated and favorable rainfed lowland ecosystems. We will conduct more strategic research on critical problems of securing yield gains and on raising the yield potential in all ecosystems through new environment-friendly technology.

IRRI's positions on priorities

We will orient IRRI's programs according to four major rice ecosystems and to the farming communities and consumers dependent on them. Collaborative research on the less favorable ecosystems will increase. Consistent with environmental enhancement and sustainability, efforts will be directed toward securing yield gains in favorable ecosystems and seeking new yield potentials in all ecosystems. Our research efforts will move upstream, to more strategic research in collaboration with other advanced institutions.

We are committed to helping strengthen national programs. Over time, we will shift from support of to collaboration with national programs and will increase the proportion of resources devoted to collaborative research and to sharing knowledge with all our partners in a mutually supportive global rice research system.

While IRRI continues to focus on Asia, fulfillment of our systemwide responsibilities will cover all regions. Reflecting IRRI's mandate and comparative advantage, we will contribute to research and to strengthening national programs in Africa and Latin America in the context of the activities of other IARCs and of donor support.

CHAPTER IV

Programs

IRRI's strategy will be implemented through two main groups of programs: research programs and international support programs. We also examine here our systemwide role in Africa and Latin America.

Research programs

The research programs for the major rice ecosystems will be interdisciplinary in nature. They will include a thorough characterization of the rice ecosystems in terms of people and their environment and of the historical, socioeconomic, and technical aspects of rice production. This characterization and analysis of the farming systems within which rice is produced will refine the definitions of the kinds of technologies that should be developed.

It will also define the conditions and criteria for evaluation that will ensure that the technologies developed have maintained or improved the natural resource base, to meet the objectives of efficiency and equity.

Irrigated rice ecosystem

Irrigated ricelands are those areas that have assured irrigation for one or more crops per year, with some areas served only by supplementary irrigation in the wet season.

On the basis of current national or regional yield averages, the irrigated rice ecosystem can be divided into areas that have the following characteristics:

- Yields higher than 5 t/ha (China, Democratic Republic of Korea, Republic of Korea, Egypt).
- Yields from 3 to 5 t/ha (northwestern and southern India, Sri Lanka, Burma, Thailand, Laos, Vietnam, Philippines, Malaysia, Indonesia).

- Yields lower than 3 t/ha (eastern India, Kampuchea, Pakistan, Nepal, Madagascar, Bangladesh, Tanzania).

Production constraints in the low- (< 3 t/ha) and medium-yield (3-5 t/ha) areas are in general the least location-specific, but they vary in frequency and intensity of occurrence. Problems include:

- Poor input management.
- Yield and quality losses from pests.
- Inadequate water supply and/or inefficient use of scarce irrigation water at both irrigation system and farm levels.
- Inadequate drainage, leading to the buildup of salinity and alkalinity.
- Environmental stresses.

While some of these problems are also found in the high-yield (>5 t/ha) areas, the main problems here include:

- An average on-farm yield plateau of about 5 t/ha in some countries (e.g., Indonesia).
- Yield instability due to pests.
- Difficulty of sustaining high yields under intensive cropping.
- Environmental degradation because of excessive inputs.

Research accomplishments for the irrigated rice ecosystem have been significant. They include development of semidwarf varieties with high yield potential (10-11 t/ha); shortening of growth duration from 150 days or longer to around 100 days; provision of greater yield stability through genetic resistance to or tolerance for pests and, to a lesser extent, problem soils; and design of associated management practices that allow the semidwarf varieties to express their yield potential. Improvements have been made in grain quality, grain size, and milling recovery. Improving nutritional value by increasing protein content has proven to be extremely difficult.

Significant challenges remain. One is to reduce further reliance on purchased chemicals, especially pesticides, by developing integrated pest management technology and integrated nutrient management using renewable resources and by breeding for resistance. This should increase a farmer's profit while reducing environmental degradation and dependency on purchased inputs. Other challenges are to overcome water stagnation and waterlogging caused by poor drainage and to lessen high water percolation rates that sometimes result in irrigation schemes being unable to service their target rice areas.

Goal

Secure and increased rice productivity, with enhanced efficiency and sustainability of irrigated rice farming systems.

Objectives

1. To raise irrigated rice yield potential from the current 10-11 t/ha per crop to 15 tons by 2010.

Until now, IRRI has considered the semidwarf rice plant as a given quantity for irrigated rice and inputs such as fertilizers and water management as constraints. The objectives have been to minimize input constraints or to maximize yields at a certain level of inputs.

We believe we should also consider the rice plant itself as a constraint and try to develop a new plant type. Our target will be to produce a rice plant with new architecture and physiological traits, to break through the yield barrier of high-tillering semidwarf varieties.

We anticipate that, due to labor shortages and with the availability of improved weed control methods, direct seeding of rice will become a more common practice. An ideal plant type for direct seeding (see foldout) should have a yield advantage of 20-30% over currently available varieties. We also will aim at incorporating all or some of the following traits into the new plant type: increased photosynthetic activity, increased light interception, improved assimilate partitioning, and improved nutrient use and uptake. New high-yielding varieties must have durable resistance to major diseases and insects and tolerance for salinity and alkalinity.

We will continue to explore the potential of heterosis, or hybrid vigor, in raising the yield potential of irrigated rice in the tropics. It is anticipated that F_1 hybrids with a yield advantage of 20% over the best available conventional varieties will become available.

2. *To develop crop and resource management techniques that will reduce production costs, increase yields, and sustain land productivity.*

Research will focus on determining the long-term effects of intensive cropping on soil fertility, soil health, soil-borne diseases, water quality, and other aspects of the plant environment; evolving efficient irrigation techniques and energy- and water-efficient tillage techniques to increase the productive use of water and lessen crop losses due to weeds; developing farm-level drainage methods to alleviate waterlogging and buildup of salinity and alkalinity; and developing techniques to manipulate and increase the availability of soil nutrients.

The very low efficiency of applied nitrogen fertilizer works against attaining the interactive goals of increasing productivity and income while reducing adverse effects on the total environment. We will aim at reducing dependence on inorganic nitrogen fertilizer by 75%, without loss of yield, through a combination of improved recovery rates of applied N and using N provided by organic sources, such as nitrogen-fixing organisms. As cropping intensification using high-yielding varieties increases, nutrients other than N, P, and K are expected to become limiting. The role of other essential nutrients in sustaining or improving yields over time needs to be better understood.

3. *To secure yield gains.*

This will be achieved partly by breeding for resistance to new biotypes or strains of insects and diseases and tolerance for soil stresses and partly by devel-

oping more durable resistance through the application of modern tools and techniques of biotechnology. The latter will be pursued in collaboration with advanced laboratories elsewhere.

4. To reduce the gap between actual farm yields and potentially attainable yields.

Efficient and economical nutrient, water, pest, and crop management practices will be developed. Identification of policy, institutional, and technological constraints to increased yields will be emphasized. Much of this interdisciplinary research will be done in close collaboration with national programs.

Rainfed lowland rice ecosystem

Rainfed lowland rice is grown in bunded fields where water depth does not exceed 50 cm for more than 10 consecutive days and the fields are inundated for at least part of the season. Such fields have no access to an irrigation system but may have on-farm rainwater conservation facilities.

Rainfed lowland rice environments are highly diverse and unpredictable. Yields are low and unstable. Crops can suffer from drought, floods, insect pests, weeds, and soil constraints. Most rainfed lowland rice farmers are poor and cannot afford to purchase many agricultural inputs.

Research has produced new cultivars and management techniques (such as dry and wet seeding and improved weed control) that have contributed to higher farm yields in the more favorable rainfed lowland environments. Knowledge of the less favorable environments has increased. Breeding lines with tolerance for submergence and late transplanting, resistance to lodging, and high yield potential have been developed. Seeding methods and implements have been developed that make feasible a change to direct seeding. Cropping systems that incorporate grain legumes and green manures show promise for raising overall productivity.

Much remains to be done, especially for the less favorable rainfed lowland areas. Breeding lines need to be more precisely tailored for and tested in the wide variety of environments, with special attention to tolerance for drought and submergence stress. Research is needed on techniques for tillage, crop establishment, water and nutrient management, and other practices.

Goal

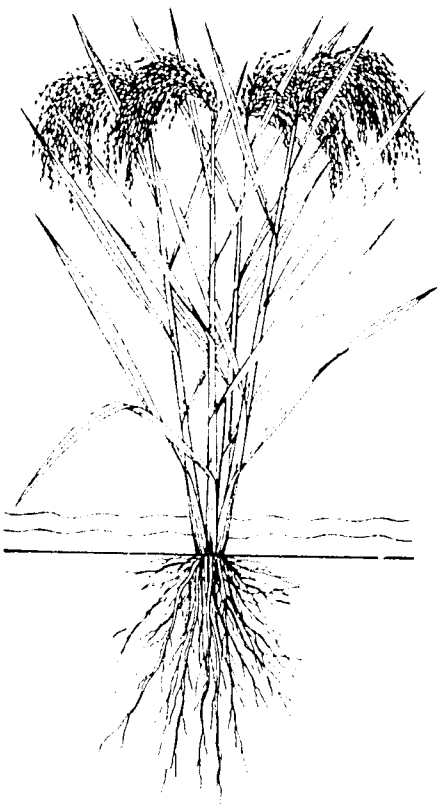
Increased productivity and yield stability and ensured sustainability of rice farming systems in rainfed lowlands, particularly in the less favorable environments.

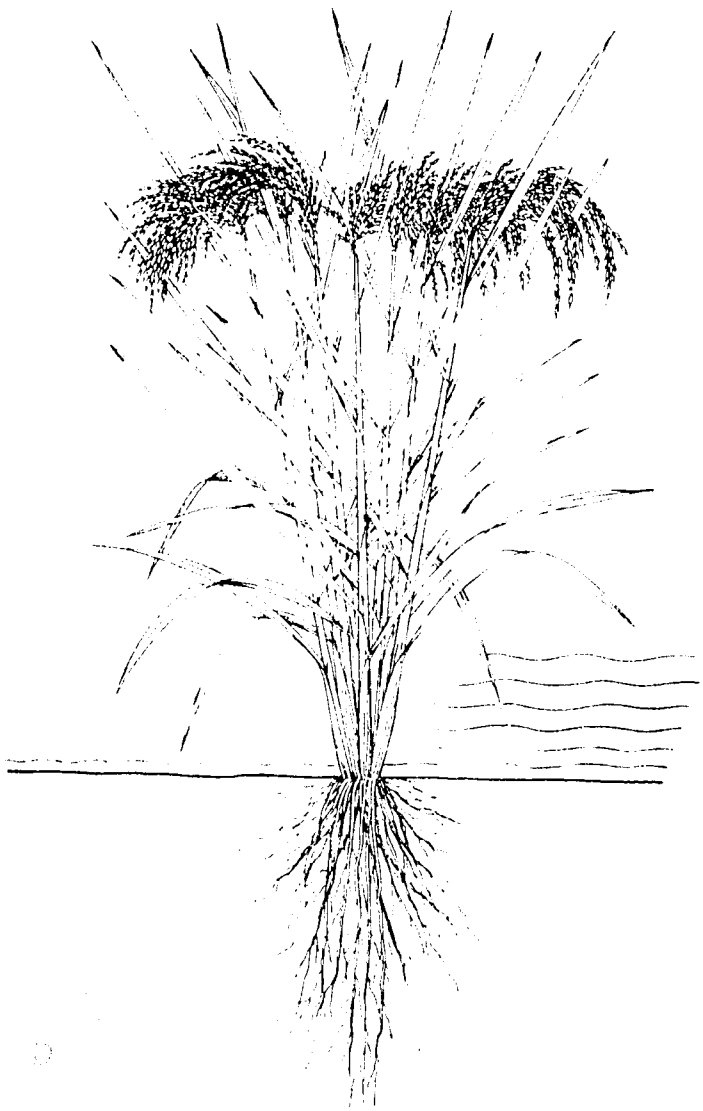
Objectives

1. To develop rice breeding lines capable of higher, more sustainable yields for the different rainfed lowland environments, with particular emphasis on tolerance for submergence and drought.

A range of improved genetic materials with a modified architecture (see foldout) will be developed for target environments. These breeding lines will

IRRI: Rice plants of the future



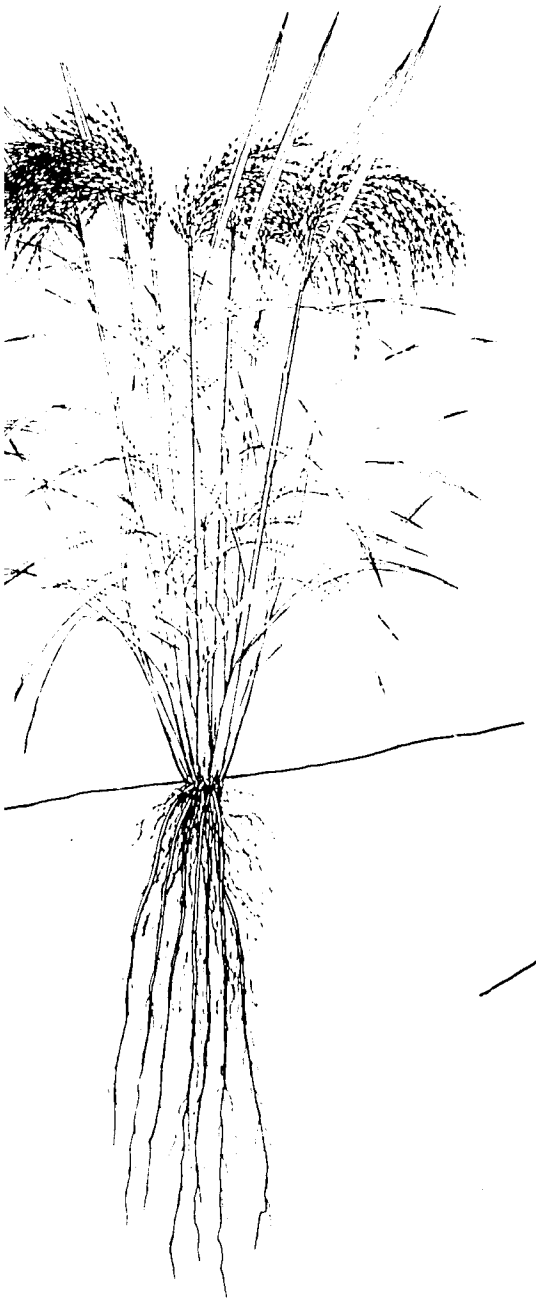


Direct seeded irrigated rice

3 - 4 panicles per plant
no unproductive tillers
200 - 250 grains per panicle
very sturdy stems
dark green, erect, thick leaves
90 cm tall
100 - 130d growth duration
vigorous root system
multiple disease and insect resistance
harvest index 0.6
13 - 15 t/ha yield potential

Rainfed lowland rice

- 6 - 10 panicles per plant
- no unproductive tillers
- 150 - 200 grains per panicle
- very sturdy stems
- dark green, erect or moderately droopy leaves
- 130 cm tall
- 120 - 150 d growth duration
- multiple disease and insect resistance
- extensive root system
- strong submergence tolerance
- strong grain dormancy
- 5 - 7 t/ha yield potential

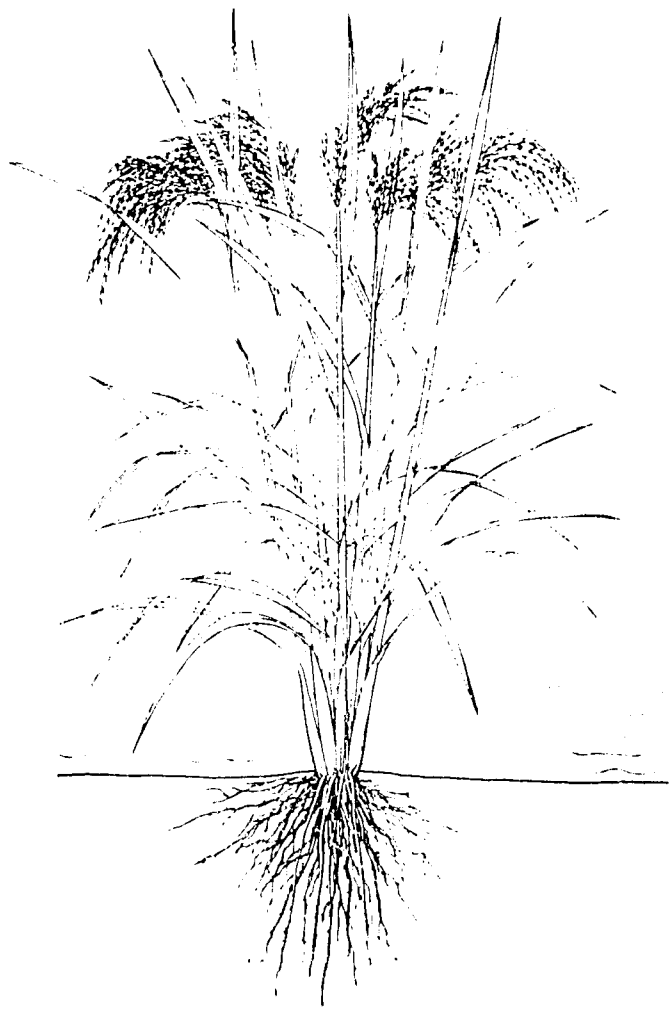


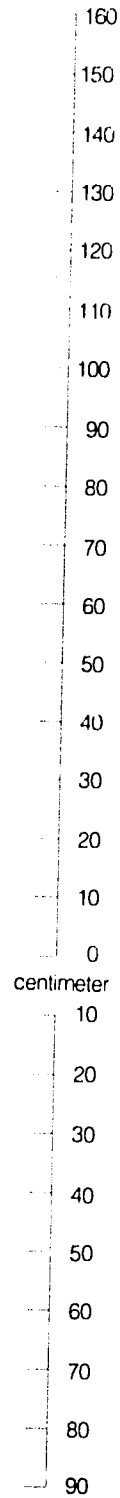
Annual upland rice

- 5 - 8 panicles per plant
- 150 - 200 grains per panicle
- very sturdy stems
- erect upper leaves, droopy lower leaves
- 130 cm tall
- deep, thick roots
- 100 d growth duration
- multiple disease and insect resistance
- 3 - 4 t/ha yield potential

Perennial upland rice

- 5 -7 panicles per plant
- 100 - 150 grains per panicle
- sturdy stems
- erect upper leaves, droopy lower leaves
- 130 - 150 cm tall
- deep, thick roots with adventitious rhizomes
- 3 - 5 yr stand in the field
- multiple disease and insect resistance
- nitrogen fixing ability
- aromatic grain
- 3 - 4 t/ha yield potential





Deepwater rice

- 5 - 7 panicles per plant
- 150 - 200 grains per panicle
- dark green, long, erect leaves
- internode elongation for 100 cm flood
- upper nodal rooting and tillering ability
- early root development
- photoperiod sensitivity
- multiple disease and insect resistance
- grain dormancy
- 4 - 5 t/ha yield potential

Tidal wetland rice

- 5 - 7 panicles per plant
- 150 - 200 grains per panicle
- very sturdy stems
- erect to moderately droopy leaves
- 130 cm tall
- photoperiod sensitive
- wide, relatively shallow rooting
- multiple disease and insect resistance
- submergence tolerance
- problem soils tolerance
- 3 - 4 t/ha yield potential

carry traits for drought resistance, submergence tolerance, yield stability, and wide adaptability in areas of unfavorable and erratic rainfall. Strategic research will determine if genes for wide adaptability and stress resistance can be transferred from wild rices to rainfed lowland varieties. That will enable us to improve our understanding of physiological responses, especially photosynthesis and uptake of nutrients and water, under alternately wet and dry soil conditions. Work on hybrid rice will be studied for its application in less favorable environments, with particular emphasis on developing yield stability through multiple stress tolerance.

2. *To develop improved production practices and systems for the less favorable rainfed lowland rice environments.*

Crop and soil management in the less favorable environments is highly location-specific. Research will aim at a more detailed understanding of the soil and crop principles underlying tillage and crop establishment practices as they relate to avoidance of drought, use of postmonsoon soil water, and total land productivity. We will include studies on the physicochemistry of alternately flooded and drained soils; the physiological effects on the rice plant of flooding and drought; techniques for efficiently using rainwater, for draining excess water, and for increasing the recovery of nitrogen fertilizer; establishing the desirable nutrient balance; and the biosystem of rice, weeds, and associated crops.

Upland rice ecosystem

Upland rice is grown in rainfed bunded or unbunded fields with naturally well-drained soils and no surface water accumulation.

Cultural practices for upland rice vary greatly. Soils tend to be acid and infertile and weed competition constrains production. In very hilly areas, a monocrop of rice is highly detrimental to environmental conservation. On rolling land, soil conservation measures developed for other crops may be useful.

Depending on market prices and geographic location, the upland farmer may choose to plant upland rice, other food crops (maize, sorghum and millet, sweet potato, potato), or cash crops (pineapple, oil palm, coffee, low-input vegetables). For most upland farmers, the costs of purchased inputs, such as chemicals and labor for weeding, are very high compared to returns.

Yields are highly variable, mostly because of drought: lack of rain for as little as 10 days at critical growth stages can reduce yields severely. Endemic disease also depresses yields.

Significant research on upland rice has been carried out for less than two decades at IRRI and in most Asian countries. During this period, an understanding of the differences among diverse upland environments has been developed through quantitative analysis and a classification of upland rice environments has been established. On-farm research has identified some major constraints to the adoption of improved cultivars and management practices.

Available upland rice germplasm has been intensively characterized and some genetic sources of superior yield potential, blast resistance, drought and acid soil tolerance, and other important stresses have been used in breeding. Knowledge about the genetics and physiology of these traits has increased. Research on how to breed for more durable resistance to blast has begun. Superior cultivars with combined stress tolerances are becoming available, but have not yet had widespread impact at the farm level.

The most serious nutrient imbalances of acid upland soils have been defined and some nutrient management practices developed. The importance of crop rotation for maintaining productivity on these soils is widely recognized and research on inclusion of grain and forage legumes in cropping patterns has resulted in the design of some promising alternative systems. Methods to integrate upland rice into hedgerow farming systems have shown potential for alleviating erosion and sustaining productivity on sloping lands.

Goal

Rehabilitated and increased stability and sustainability of upland rice farming systems .

Objectives

1. To design a range of rice production practices that will help rehabilitate the uplands and transform them into sustainable agroecosystems.

Resource management and rehabilitation techniques will focus on soil fertility maintenance and improvement of soil and water conservation, using trees, shrubs, and grasses integrated with diversified cropping systems and exploiting crop and livestock interactions, in cooperation with other IARCs. Development of acid-tolerant breeding lines and organic fertilizer technologies will require understanding the mechanisms of acid soil tolerance, the amelioration of acid soils, and the socioeconomic constraints that upland rice farmers face. Methods and implements to control weeds more efficiently, with less labor, and rice plant types that are competitive with weeds are needed.

2. To develop techniques and technologies for increasing and stabilizing rice yields.

Research will be directed toward:

- Designing crop and water resource management systems that conserve moisture for crop use and improve drought escape.
- Identifying the physiology and inheritance of traits for drought tolerance.
- Developing a broad gene pool of improved materials (see foldout) with drought tolerance, durable blast resistance, weed competitiveness, and tolerance for acid soils.
- Tracing the inheritance of blast resistance by studying cultivars with durable resistance.
- Determining the interactions of blast with drought, soils, and mineral nutrition.

- Designing integrated pest management practices to reduce variability in output due to diseases and insects.

3. *To develop a perennial upland rice cultivar by 2010.*

A perennial rice cultivar should tolerate diseases, pests, low temperature, and drought and have nitrogen-fixing properties, competitive ability, and adaptability to adverse soils (see foldout). To guide the breeding program, a study that simulates the complexity of continuous rice in the upland ecosystem will be designed. It will provide data on the probable effects of insects, rats, birds, weeds, and other pests and diseases and insights into how a perennial rice might be integrated into upland farming systems.

Deepwater and tidal wetland rice ecosystem

Deepwater rice areas are those where rice grows under rainfed dryland or shallow flooding conditions for 1-3 months, then is subjected to flooding with water depths of over 50 cm for a month or longer. Where water levels are over 100 cm, the crop is usually called floating rice. Tidal wetlands occur where water levels in the ricefields fluctuate under the influence of tides.

The rice varieties now grown in these environments have a long history of adaptation. But yields are still low and unstable. There are five main problems:

- In the wet season, farmers have little choice for crops other than rice.
- Deepwater rice is subject to problem soils and to both drought and deep flooding.
- Flooding patterns differ between seasons and cause highly variable stresses.
- Tidal wetlands are subjected to fluctuating water levels, salinity, and severe soil stresses (acid, acid sulfate, peat).
- Rice varieties for deep water are susceptible to stem borers, for which there is no known resistance, and to the nematode that causes ufra.

Research accomplishments include the development of plant prototypes, prebreeding, and varietal improvement. However, in comparison with the research resources devoted to the more favorable environments, those for the deepwater and tidal wetland ecosystem have been much less, both at IRRI and in national programs. Progress has been constrained by the difficulty of fitting varieties to the wide range of highly diverse, poorly understood environments.

Screening is used to select for elongation ability and tolerance for submergence, drought, problem soils, and pests, but the inheritance mechanisms for these traits are incompletely understood. Varieties for tidal wetland areas need to be highly efficient in their use of deficient minerals. Although some new plant prototypes are available, field evaluation trials often fail because of seasonal variability and very few genotypes have been tested in farmers' fields.

Goal

High and stable rice production in deepwater and tidal wetland areas.

Objectives

1. To develop rice breeding lines capable of higher (3–4 t/ha) and more stable yields, with improved tolerance for floods, drought, pests, and problem soils.

The immediate target environment is areas where maximum water depths are less than one meter. Initial crosses and early selection will be done at IRRI, with varietal selection done by national programs in their particular environments. Strategic research at IRRI, in collaboration with advanced laboratories elsewhere, should include investigation of the genetics, physiology, and mechanisms of tolerance for flooding and for various problem soils.

Our target for deepwater rice is more efficient partitioning of biomass for grain production; for tidal wetlands, it is improved salt- and submergence-tolerant varieties (see foldout).

2. To develop rice-based cropping systems that increase land use efficiency.

Research will focus on better management of soils, water, and crops. Emphasis will be on increasing total productivity. Crop intensification could include introduction of early-maturing rice, rice ratooning, intercropping rice and other crops, and intensification of preflood and postflood cropping patterns. Fish production is an essential component. Economic assessment of new production systems will be included.

3. To develop crop and resource management practices for unused deepwater and tidal wetland areas.

With large areas of not-yet-cropped deepwater and tidal wetlands, South and Southeast Asia, Africa, and South America have considerable potential for expanded cultivation. Breeding lines and production practices will be developed for those areas.

Cross-ecosystem research

The challenges of the future are likely to be more complicated than those we have had to address in the past. To meet them, we need anticipatory research, in which we adopt a futuristic role toward sustaining gains in rice science. Such research will make use of new techniques and newly developed tools and will bridge basic research done at other advanced institutions, IRRI's four ecosystem-specific programs, and national rice research systems.

This program will include research that aims to generate knowledge applicable to more than one ecosystem or that needs to be conducted in two or more ecosystems. Research applicable primarily or initially to a single ecosystem will be administered under the appropriate ecosystem-specific program.

We have the following comparative advantages for doing cross-ecosystem research:

- We are able to mobilize the expertise needed to solve problems, even if it is not located at IRRI.

- We have well-established links with national rice research systems and can act as a bridge between scientific knowledge being generated worldwide and the needs of national programs.
- The results of broad-based research done at IRRI can benefit a large number of national programs.

The research agenda we envisage must be flexible, so that IRRI can capitalize on new ideas and tools and respond quickly to unanticipated rice production and sustainability problems. This program will provide the ecosystem-specific programs with knowledge needed to better design their problem-oriented projects.

Objectives

To increase understanding of rice ecosystems; to develop modern scientific tools, methods, and knowledge for addressing current and anticipated rice production problems common to several ecosystems; and to make available to national programs promising technologies arising from more basic research.

Some examples of research activities that will contribute to meeting these objectives include:

- Characterization of the physical, biological, and socioeconomic conditions of rice ecosystems, particularly in the less favorable ecosystems.
- Transfer of genes for disease and insect resistance from wild relatives of rice into cultivated rice, with exploitation of new genetic variability for improving yield and grain quality.
- Characterization of the bases for resistance to selected diseases and development of methods to breed for durable resistance.
- Investigation of the biology, ecology, and population dynamics of pests (insects, pathogens, weeds) and beneficial organisms, as a basis for developing practical pest management systems.
- Development of screening methods for cooking and eating qualities of rices within the same amylose class.
- Development of participatory research methods for on-farm systems research.
- Investigation of the interactive impacts of technical change in rice farming systems on productivity, stability, environmental sustainability, socioeconomic conditions, and target beneficiary groups.
- Investigation of the role of resource allocation in farming systems design and its relationship to sociopolitical institutions.
- Reduction of harvest and postharvest production losses, including the development of wet season drying procedures and threshing and milling equipment.
- Development of efficient means to control rats in ricefields.

International support programs

A fundamental objective of the CGIAR is to help strengthen national research capabilities. Since its founding, IRRI has played a major role in fostering the growth of a global family of rice research institutions and scientists. Training and other knowledge-sharing activities, including scientific publication, bibliographic services, conferences and workshops, databases, networks, resident scientists, and scientist-to-scientist collaboration, have been used to strengthen national research capabilities.

International support programs during the next 10 years will have five major components:

- Germplasm conservation and dissemination.
- Information and knowledge exchange.
- Networks.
- Training.
- Technical support.

We will aim for close integration of the research programs and the international support programs. Some support programs will be increasingly oriented toward and funded through the research programs. Continuing dialogue, particularly with national programs, will guide the nature and scope of our support activities. Over time, they will be seen less as support activities and more accurately as special contributions to international rice research.

Objectives

To support and strengthen the rice research capacity of national systems and to serve the international rice research community.

Germplasm conservation and dissemination

A continuous supply of diverse germplasm, including traditional varieties, improved breeding lines, wild relatives, and grasses in rice-related genera, is crucial to raising yield potential, stabilizing yields, and enhancing the sustainability of biotic ecosystems. From 1972 to 1988, 44,000 seed samples of unimproved varieties and wild species were collected in 14 Asian countries. That increased IRRI's holdings to 81,000 cultivars and 2,400 wild rices, considerably enriching the genetic diversity available for future use. The current focus is on assembling wild species and providing duplicate storage security for national collections.

Since 1962, more than a million seed samples have been supplied researchers at IRRI and in national programs. Recently, IRRI provided duplicates of national collections to five Asian and two African countries and to two states in India. Exotic rice germplasm for genetic engineering research all over the world comes almost exclusively from the IRRI collection.

Objectives

To collect, preserve, document, and study the world's rice germplasm and to provide free access, worldwide, for its use in rice research and rice crop improvement.

IRRI will systematically explore, on a global basis, unprotected rice germplasm in existing collections and in natural habitats and incorporate new accessions into the base germplasm collection. We have capacity for about 130,000 accessions.

In field collection, tropical Asia will be the principal responsibility of IRRI, in collaboration with national scientists. In germplasm-rich niches outside Asia, we will collaborate with other IARCs (IBPGR, IITA, CIAT, WARDA) and with concerned national programs to explore and collect material.

Maximum security will be ensured through duplicate storage and through consolidation of conserved materials. Research on preservation technology will add to the security of all collections.

We will characterize, evaluate, and document our collections and make seeds and related data available to all rice researchers and to national collections. We will continue technical collaboration with other genebanks and expand information activities to increase public understanding of the crucial role genetic conservation plays in food crop security. We will study our collection and an expanded pool of related genera to evaluate their potential usefulness.

Information and knowledge exchange

IRRI has a mandate to disseminate the research findings of the Institute, to make available literature on rice worldwide, and to organize conferences and workshops. These information and knowledge exchange functions are no less important today than they were at IRRI's founding. They should be expanded by broadening the scope of rice-related data being collected and disseminated and by intensifying efforts to ensure that the public is accurately informed about rice research and IRRI.

This component of international support programs has five parts: library, scientific publication, rice databases, conferences and workshops, and public awareness.

LIBRARY

The IRRI Library is the major world repository of rice literature. It has its own computerized Rice Literature Search Service, with more than 125,000 entries, and has access to the AGRICOLA database for specialized discipline-related materials. The Library has published a 10-year bibliography (1951-60), 27 annual supplements, and 5 cumulative indexes. It also has issued several bibliographies covering azolla, cropping systems, and other topics. It routes the tables of contents of international journals to scientists of the rice world, provides copying and document delivery services, and handles translation work. A small office is maintained in Japan, the source of an estimated 40% of the world's rice literature.

Objectives

To collect and document the world's literature on rice and to provide free access worldwide.

We will continue to improve current services and will expand accessibility through the following activities:

- Continuously acquiring retrospective and current literature on rice for dissemination worldwide.
- Improving library services through increased reliance on computer and other modern technology for information storage, retrieval, and dissemination.
- Developing linkages with libraries in rice-producing countries.
- Regularly publishing bibliographies on relevant topics and translating into English selected materials originally published in other languages.

SCIENTIFIC PUBLICATION

IRRI publishes about 25 scientific books and 3 major periodicals a year. Annual distribution is about 200,000 books. Twenty-eight books have been translated into 43 languages spoken in 27 countries. We have an extensive audiovisual series, with six video films produced in 1988.

Objectives

To publish scientific information and to promote the flow of current rice research knowledge to scientists worldwide.

To improve publication efficiency and focus, we will undertake the following activities:

- Categorize IRRI scientific publications according to our research programs, identify gaps where publication is needed, and plan publications with the scientists involved in the programs.
- Evaluate new information distribution techniques and technologies to speed the exchange of information among scientists worldwide.
- Adapt new processes and strategies for scientific communication.

RICE DATABASES

Complete and continuously updated information on rice environments and relevant research findings is needed to identify critical problems and the research needed to solve them. IRRI has addressed this need by developing databases which, so far, concentrate primarily on research and research support information. These are:

- Research data generated at IRRI and by IRRI scientists in collaboration with partners in national programs. The major databases are the germplasm data bank (passport data, morphoagronomic characteristics, evaluation results), parentage of rice crosses, inventory of selections of promising

lines from IRRI crosses and their performance, and results of network nurseries and trials conducted worldwide.

- Secondary data on rice production and production inputs, consumption, trade, and prices in major rice-growing countries (1950-1987).

Objectives

To compile, continuously update, evaluate, interpret, and disseminate primary and secondary data on rice and the physical, biological, and socioeconomic environments of the rice ecosystems and to establish linkages with relevant databases outside IRRI.

We will increase the coverage of existing databases to include:

- Current research and development activities of national rice research systems and rice scientists worldwide.
- Edaphic, biological, technical, climatic, and human aspects of rice ecosystems.
- Marketing and public policies linked to rice.

Accessibility of databases within and outside IRRI will be improved. We will synthesize and integrate existing databases and make them available on a local computer network within IRRI and, through improved telecommunication facilities, to researchers worldwide.

CONFERENCES AND WORKSHOPS

To date, IRRI has sponsored or cosponsored more than 250 conferences, meetings, and workshops, covering a broad range of topics. During the last decade, IRRI also hosted conferences related to rice research sponsored by FAO, UNDP, various universities, and other international organizations. The annual International Rice Research Conference, begun in 1963, aims to review the progress of rice research and to formulate action plans for the future. As a politically neutral and commercially disinterested research institution, we have a particular advantage in initiating discussions of the impacts of rice technology on people and the environment. We intend to invite representatives of many different interest groups to occasional consultations to facilitate an ongoing dialogue about the relationship of new knowledge and agricultural policymaking.

Objectives

To facilitate the participation of scientists from all our collaborating institutions in the setting of program priorities, planning of research, sharing of research results, and promoting of dialogue on institutional and policy issues.

The personal interactions fostered by conferences and workshops are an irreplaceable impetus for the enhancement of scientific collaboration, the exchange of scientific information, and the advancement of knowledge. As IRRI moves to increase its collaborative partnerships in a mutually supportive global research system, these forums will increasingly be used to set priorities, monitor programs, establish research agendas, and discuss institutional and policy issues. In the

future, the annual International Rice Research Conference will concentrate more on particular themes. We will increase our monitoring of the implementation of conference and workshop recommendations.

PUBLIC AWARENESS

The number of press releases distributed by IRRI recently increased, from about 10 a year to 40 in 1988. Some 80 journalists visited the Institute in 1988. Video production in cooperation with Philippine agencies started in 1988 and a mass media information service is being developed.

Objectives

To create an accurate understanding of rice, rice research, and IRRI's goal, objectives, programs, and approaches among donors, policymakers, and the general public in both developed and less developed countries, particularly in IRRI's host country, the Philippines.

IRRI will disseminate news about rice research activities worldwide, with due acknowledgment of our partners and other cooperating agencies. Communication professionals in different regions will be able to add elements of local interest to IRRI materials and, where necessary, translate them. We will maintain a computerized list of the specific interests and purposes of different media to improve the focus of news materials.

We will also refine our mechanisms for eliciting feedback from the different audiences interested in and affected by rice, rice research, and agricultural development.

Networks

Networks link national program scientists with each other and with IRRI and other international and regional centers. Three major networks are coordinated by IRRI:

- The International Rice Testing Program (IRTP) is a network to exchange and evaluate improved genetic materials in different rice-growing countries. The materials come from national rice research systems and IRRI, IITA, CIAT, and WARDA. Each year, 28 types of nurseries are organized for different target environments and for various physical, chemical, and biological stresses. More than 50 countries in Asia, Africa, and Latin America participate. Genetic sources of tolerance for various stresses identified through IRTP have been utilized in several national breeding programs. Cooperative efforts among national programs and IRRI have led to the release of 170 entries as varieties in 47 countries.
- The International Network on Soil Fertility and Fertilizer Evaluation for Rice Farming (INSFFER) became the International Network on Soil Fertility and Sustainable Rice Farming (INSURF) in 1988. INSFFER focused primarily on N fertilizer use efficiency. With INSURF, national programs

are encouraged to lead in generating additional technologies relevant to nutrient management and soil conservation problems in specific areas, with an emphasis on renewable resources. More than 60 scientists from 18 countries participated in 1987. More than 200 researchers from 90 institutions in 26 countries have been trained on methodologies for conducting soil fertility and fertilizer management trials.

- The Asian Rice Farming Systems Network (ARFSN) facilitates collaboration among scientists in 16 national programs, IRRI, and other international centers in identifying more productive and sustainable rice-based farming systems that are acceptable to small farmers. The other international centers help to provide the improved varieties of nonrice crops (e.g., wheat, mungbean) that form part of the farming systems.

Objectives

To strengthen collaboration and facilitate the exchange of technologies, research methodologies, and knowledge among national rice research systems, IRRI, and other international centers, with particular reference to the four main rice ecosystems.

IRTP will increase its attention on less favorable environments. Network activities will cover Asia; East, Central, and Southern Africa; West Africa (in collaboration with WARDA and IITA); and Latin America (in collaboration with CIAT).

INSURF will emphasize the alleviation of soil problems through integrated nutrient management and soil conservation measures and the reduction of production costs through efficient use of inputs and partial substitution of farm-produced inputs for purchased inputs. The focus will be on irrigated, rainfed lowland, and upland rice ecosystems. Linkages with other international networks involved in soil management research will be strengthened.

ARFSN will continue to enhance the research capabilities of national programs in developing farming systems technology that will increase farm productivity and farm incomes. More work will be done on participatory research methods. It will facilitate linkages with other networks that deal with specific technology components.

As IRRI's strategy evolves, other relevant networks may be developed. The network component of our international support programs will become more closely linked with the research programs. The networks themselves will be increasingly integrated, with part of the responsibility for coordination shifting to national rice research systems that have a comparative advantage.

Training

More than 5,000 rice scientists from 78 countries have participated in IRRI training programs during the last 27 years. These alumni are now contributors to the pool of rice research and knowledge and occupy important positions in many national rice research systems.

Our training programs include postgraduate training, nondegree training, development of course materials, and course transfer.

We maintain liaison with 29 universities worldwide in cooperative research and scholastic programs. The postgraduate population in 1988 consisted of 20 postdoctoral fellows, 43 Ph D degree candidates, and 33 MS degree candidates affiliated with these universities. These scientists contribute to rice research efforts both at IRRI and in their home countries.

We conduct 9 regular short-term courses and 4-5 special courses a year for about 250 scientists from 30-35 countries. IRRI's training strategy emphasizes participatory problem-solving activities in the scientific disciplines related to rice. In order to apply the most current knowledge in cognitive psychology and adult learning, a significant share of training resources is devoted to development of course materials.

Objective

To conduct training programs that will assist national systems in developing a critical mass of professionals working to advance rice science and to solve rice production and utilization problems.

Training for national program scientists will be directed to these changing needs of national programs, using advances in educational technology. IRRI will:

- Focus training efforts toward selected national research institutions in each country, so that critical masses of scientists can be formed at strategic locations.
- Establish evaluation and feedback mechanisms to ensure that IRRI's training efforts continue to serve national needs and remain relevant to meet emerging problems.
- Provide training on new research techniques.
- Encourage and, where appropriate, assist universities in collaborating countries to initiate short-term courses for national rice scientists and to offer the academic components of MS and Ph D degree training, with thesis research to be undertaken at IRRI. To support this activity, we will bring key university staff to IRRI for practical and advanced training. For more specialized training, we will increase the number of universities with which we have collaborative graduate degree programs.
- Expand efforts to support national training capability in rice research. We will transfer selected short-term training courses (e.g., rice production, integrated pest management, farming systems) to national and regional institutions with the capability to train their own people and those of other countries. This will involve documenting rice science and technology in a training format that is readily transferable and adaptable to national systems.

- Develop training strategies and instructional materials that ensure that the most effective methods are used at IRRI. This will include examination of language and cultural barriers that impede learning.
- Initiate training on rice-related research management, in collaboration with ISNAR and other relevant institutes.

Technical support

This program enables IRRI to respond to specific needs of rice-growing countries, recognizing that the needs may be met in part by collaboration for research and training. Since its inception, IRRI has provided direct technical support to national rice research systems through short- and long-term assignments of scientists. The scope and duration of such projects have varied greatly. Over the last decade, the number of requests for technical support has grown and some countries with long histories of IRRI cooperation and collaboration have requested project extensions.

In helping to develop the rice research capacity of groups of neighboring countries, some or all of which may have relatively small rice areas, we have found it more practical to provide assistance through regional projects. In these cases, it is difficult to undertake an effective country-specific project approach without overextending IRRI's managerial and staff support capabilities.

Objectives

To provide technical support to national programs that seek IRRI's cooperation.

In establishing priorities to direct the allocation of our limited resources for technical support, we will give highest priority to countries with insufficient rice research capacity, low rice yields, high dependence on rice, and low per capita income. In addition, the following considerations will be applied:

- An official request from the country concerned.
- A clear national policy to increase rice production and productivity.
- Potential for increasing rice productivity or expanding rice-growing area through location-specific research.
- Willingness to share the results of cooperation with other countries.
- Comparative advantage for IRRI to provide the level and scope of cooperation being requested.
- Potential contribution to the objectives of one or more IRRI programs.

IRRI will not play a major role in research infrastructure development nor in providing research equipment. However, where these factors are seen as important constraints to national rice research program development, IRRI will, at the request of a national program, assist in identifying possible sources of support. Through dialogue with national program leaders and with donors and related agencies, IRRI will make every effort to ensure complementarity with other research and development agencies.

IRRI's systemwide role

IRRI in Africa

WEST AFRICA

There is every prospect that the quality and impact of rice research in West Africa will be substantially greater in the future than it has been in the past. WARDA has a clear mandate for rice research to serve 16 West African countries with 2.6 million ha of riceland. IITA will continue research on rice-based farming systems but its rice improvement activities for West Africa will gradually be incorporated into the WARDA sphere of operations.

IRRI is committed to support WARDA in fulfilling its mandate and will locate at least one scientist at WARDA headquarters to liaise between the two institutes and to participate in WARDA's scientific program. IRRI will not develop independent country programs in the region covered by WARDA but will work through and with WARDA in meeting expressed needs of countries for collaboration in training and research. The IRTP-West Africa Program will be undertaken as a joint activity of WARDA and IRRI.

EAST, CENTRAL, AND SOUTHERN AFRICA

The African continent has 2.4 million ha of ricelands outside the WARDA mandate area. IRRI will continue to accept responsibility for assisting rice-growing countries in East, Central, and Southern Africa to strengthen their national rice research capabilities.

Egypt and Madagascar are the major rice-growing countries in this region, with a total rice area of 1.6 million ha. Our programs to strengthen the national rice research systems in these countries will continue. In other rice-growing countries of the region, Tanzania, Zaire, Mozambique, and Malawi have the largest areas, with 0.8 million ha of ricelands, predominantly in the rainfed lowland rice ecosystem. Another 1.0 million ha in East, Central, and Southern Africa have potential for rice cultivation.

Objectives

We have been considering four models for increasing our involvement with countries in this region:

- Develop a regionally based scientific team to work on rice research problems common to a group of countries.
- Develop specific country programs, with a team of scientists based in country.
- Strengthen the training of rice scientists in national programs.
- Establish intercenter collaboration, in which several IARCs share facilities, pool resources, and develop joint programs based on ecosystems.

Action has been taken on models one and three; initial discussions with CIAT and IBPGR encourage us to pursue model four. An IRRI scientist has been stationed in Tanzania to coordinate IRTP network activities in the region and to liaise with individual countries on training and research.

Our strategies for this region relate to both research and training.

Research. A team of scientists located in one country would conduct applied and strategic research at key irrigated and rainfed lowland ecosystem sites in several countries. The scientists also could provide additional support to the outreach programs in Madagascar and Egypt. Team members would supervise postgraduate research.

Training. Almost all training for West Africa will be conducted at WARDA. Trainees from East, Central, and Southern Africa will, whenever possible, be trained in the region, using national facilities or those of other international centers. Scientists at key sites in the region also could conduct training. Training in specialized fields will continue to be done at IRRI headquarters.

IRRI in Latin America

Latin America and the Caribbean produced 18.4 million tons of rough rice from 8.2 million ha in 1987; average yield was 2.2 t/ha. In the 12 major rice-growing countries in this region, irrigated rice accounts for 32% of the total area; upland, 62%; and rainfed lowland, 6%. Deepwater rice is grown on a negligible area but there is considerable potential.

CIAT collaborates with Brazil, Colombia, Peru, and Panama, mostly in irrigated rice research. CIAT has increased its research on upland rice, particularly for the favorable environments of that ecosystem, and has developed several promising lines based on progenitors from Latin America and Africa.

The major bottlenecks for upland rice are drought, poor soils, and diseases (mainly blast). In the irrigated and rainfed lowland areas, the predominant problems are salinity, iron toxicity, low temperature, diseases, and insects. IRTP has been the major activity of IRRI in Latin America, implemented jointly by IRRI and CIAT since the mid-1970s. Many IRTP entries from IRRI and Asia perform well, mostly in irrigated areas. Some entries show good levels of tolerance for cold, blast, and salinity. Most CICA lines (bred jointly by CIAT and ICA) have IRRI lines in their parentage and 28 IRRI breeding lines have been named as varieties in 20 countries in Latin America and the Caribbean.

We have trained 92 scientists from the region and scientists from Latin America participate regularly in conferences and workshops at IRRI. Many materials in IRRI's Germplasm Center and Library are from Latin America. We have two liaison scientists, one at CIAT and one in the Dominican Republic.

Objectives

Except for some specific stresses, rice production problems and constraints in Latin America are similar to those in Africa and Asia. CIAT has a regional

mandate, IRRI a systemwide mandate for rice. Our activities, therefore, will be complementary, in close collaboration with CIAT and with concerned national programs. The main features of IRRI's program in Latin America will be as follows:

- We will concentrate on the irrigated and upland ecosystems.
- For irrigated rice, we will respond to specific requests and collaborate on such activities as germplasm collection and dissemination, exchange of improved genetic materials, salinity and low temperature tolerance, ecosystem characterization, water balance simulation, water/soil management, small farm machinery, soil microbiology, and socioeconomic studies.
- For upland rice, we will concentrate on drought, blast tolerance, and adaptation to poor soils.
- We will continue IRTP activities and explore participation of Latin American countries in the INSURF network.
- We will facilitate translation of IRRI publications into Spanish and increase the participation of Latin American rice scientists in IRRI-sponsored conferences and workshops.
- We will pursue collaboration with CIAT through such activities as participation of scientists in each institute's internal program reviews, intercenter collaborative workshops, and knowledge and resource sharing.

CHAPTER V

Collaboration

IRRI's strategy calls for increasing the range and degree of collaboration with many different types of research institutes and systems. This will enhance our effectiveness in meeting both of IRRI's general objectives: conducting relevant research and helping to develop national rice research capability. In many cases, the same activity will contribute to both objectives, reflecting our view that often the search for new knowledge is best done as a joint endeavor. That leads to better research and to stronger research systems.

We define collaboration as cooperative work with other institutions on specific activities designed to meet mutually defined objectives. Each party contributes some form of resources. It should be stressed that each proposal for collaboration will be tested against a fundamental question: Will it contribute effectively to achieving our objectives and, ultimately, the goal?

Research collaboration

Our collaborative agreements will take different forms, depending on the knowledge sought and the resources available. The irrigated rice ecosystem is homogeneous and, to a large extent, can be simulated on a research station. However, more than half of the rainfed lowland rice ecosystem and most of the upland and deepwater and tidal wetland rice ecosystems are unfavorable rice-growing environments with considerable heterogeneity. For those environments, we can ensure research relevance and productivity only by working closely with our partners in the national systems and in the ecosystems themselves. Within the research programs, almost all IRRI projects in the irrigated rice ecosystem program and strategic projects in the other programs will be done at IRRI headquarters.

The problems in the less favorable ecosystems are more difficult. We must use care in selecting research sites, in deciding which program components

should be done at which sites (i.e., at IRRI headquarters or elsewhere), and in maintaining the linkages among all research sites. Significant breakthroughs and solutions to problems are expected to take longer in the less favorable ecosystems than in the irrigated ecosystem and long-term commitments will be necessary.

Mechanisms

We believe that, for the less favorable rice ecosystems, the benefits derived from applied research conducted by IRRI will be limited unless much of the work is done on site, in collaboration with the national programs concerned. Relative costs to IRRI and the national programs will vary, depending on the mechanisms chosen. We will weigh the benefits and costs of collaborative research proposals against the criteria laid out in Chapter III. Alternatives will be defined in terms of different ways of carrying out the research and of potential benefits and costs.

The following collaborative mechanisms have been identified as possible alternatives. They are not mutually exclusive—indeed, many are complementary—nor is the list exhaustive. The examples are only a selection from a wider spectrum of possible collaborative mechanisms. The optimal solution for a particular research project may draw upon several approaches simultaneously and/or in an evolutionary sequence, starting with a relatively modest approach and adding elements over time.

- Outreach. IRRI scientists are posted to a national program, to work in its rice research projects and to strengthen its linkages with IRRI's research and with that of neighboring countries.
- Joint venture. A research activity focused on a specific topic (e.g., peat rice soils) is conducted jointly, with cost sharing, by IRRI and a collaborating institution. IRRI scientists usually are not posted for an extended time to the host institution.
- Visiting IRRI scientist. An IRRI scientist is posted temporarily to another advanced institute that has a comparative advantage of importance to IRRI, to work on a particular problem.
- Key sites. Teams of national scientists are formed to work in their own countries, at research sites representative of one or more ecosystems in more than one country. The research is funded and administered by IRRI in cooperation with the host institution. IRRI scientists usually are not posted at the site, although short-term appointments are possible. Facilities may be leased.
- Contract research. A research project is identified jointly by IRRI and an institution with the relevant comparative advantage. The research is funded by IRRI and executed by the research institution selected.
- Regional consortium. Two or more national institutions are formally linked in an integrated project focused on a particular problem that draws upon the respective strengths of each institution (e.g., Upland Rice Drought/Blast Consortium).

- Network. Several national programs are linked on a continuing basis to exchange knowledge and plan joint activities. The subject matter of the network may be a function (rice testing) or a research topic (soil fertility). The hub, or coordinating center, of networks traditionally has been IRRI. While this mechanism is similar to a consortium, it stresses research strengthening and technology evaluation rather than narrowly defined research objectives. It also is usually at a lower cost to a national system.

Choices

The criteria for choosing research partners are as follows:

- Agreement on a common objective.
- Complementarity of the strengths of each research institution.
- Scientific standards and relevance.
- Mutual belief in IRRI's goal and guiding principles.
- Adequate financial resources.

We are conscious of the risks in collaboration: a stronger organization can dominate a weaker one and striving for high standards can be interpreted as arrogance.

With increased emphasis on ecosystems, different networks will have a common basis for integrating their activities; that can enhance interaction among teams of scientists working at key research sites. IRRI's experience with networks can be used as a basis for establishing regional consortia with ecosystem focuses.

The least expensive and most flexible collaborative mechanisms—outreach, joint venture, and visiting IRRI scientist—offer great scope. Examples of the visiting-IRRI-scientist approach could include posting a soil microbiologist at the Chinese Azolla Research Center or sending a biotechnologist to a European institute to gain experience in working with new agrobacterium transfer techniques.

As a variant to the visiting-IRRI-scientist approach, an IRRI scientist could carry out part of a research activity at IRRI, part at an advanced institution in an industrialized country, and part in the national program of a rice-producing country. This approach to research could enhance international collaboration, especially if it were combined with a joint venture to give a scientist from a national program an opportunity to work in an advanced research institution elsewhere.

Relationships between IRRI headquarters and national programs can be considerably enhanced by relatively minor investments in modern electronic communications technology. With telecommunications, collaborating scientists can maintain virtually continuous dialogue, if necessary. That could increase the productivity of site visits.

Partners

We recognize that, in the broad sense, universities are part of a national research system. We intend to increase our collaboration with universities, both for research and for training. The research potential at universities is often underexploited, to the detriment of their teaching role and of national development. We will form networks of universities with specific research focuses. That will draw more university staff into collaborative research, not just with IRRI but also with each other. For example, the knowledge base in rural socioeconomics could be enhanced and mobilized through university-based networks.

We also will develop collaborative relationships with non-national research institutions, especially with international centers within and outside the CGIAR, as we have done with ICIPE and IFDC. In addition to our work with IBPGR, CIAT, IITA, and WARDA, we will need to work closely with ISNAR and IFPRI on such topics as research planning and national rice policies.

Scientific collaboration also will be supported by short-term visits to national programs by IRRI headquarters staff and by special consultancies. National scientists will continue to be encouraged to visit IRRI headquarters to develop and review plans for collaboration.

Collaboration to enhance national systems

Many of the mechanisms described as valuable in collaboration for research can also be used to help develop national programs. However, the benefits tend to be greater and management simpler if it is clear which components of a collaborative activity are directed to which objective. Some mechanisms are best targeted to only one objective. For example, networks tend to become unproductive when member institutions differ greatly in their research capabilities: the stronger institutions can become frustrated while the training effect on the smaller, less complete research systems is minimal.

Concentration of research effort in the past on the favorable environments has resulted in a significant accumulation of knowledge, experience, and capability. The knowledge and capability specific to the less favorable environments are less. As we shift more of our attention to the less favorable environments, collaboration, especially through such mechanisms as key sites and regional consortia, will be particularly valuable as means of mutual learning. IRRI will be increasing its own capabilities with respect to these environments in concert with its national partners.

CHAPTER VI

Implementation

Reorganization is an integral part of IRRI's strategy. Both quantitative and qualitative change will occur: the overall aim is increased focus on problems and environments, using an interdisciplinary approach supported by discipline-based divisions. Here we state our commitment to change and describe in broad terms our program management and resource allocation plans. Further details and an organization chart will be provided in the five-year plan.

Program management

Structure

Historically, IRRI's programs have been implemented primarily through discipline-oriented departments. The discretion and flexibility this system gives to department heads have contributed greatly to IRRI's achievements. However, the new CGIAR approach to planning and budgeting and our own evaluation of IRRI's present organization and future prospects have led to the decision to shift to a budgeting system based on interdisciplinary programs. The existing 13 disciplinary departments and 8 global research services will be grouped into a smaller number of divisions. Projects will be implemented through research programs and international support programs. As shown in Figure 7, the two sets of programs will draw upon research services, administration, and finance.

The organization of IRRI's work is more complex than is implied in the figure. There are two types of programs, but several activities do not fall neatly into either one. For example, networks serve a dual role: as ways to carry out research and as means to strengthen national research capability. Generation of

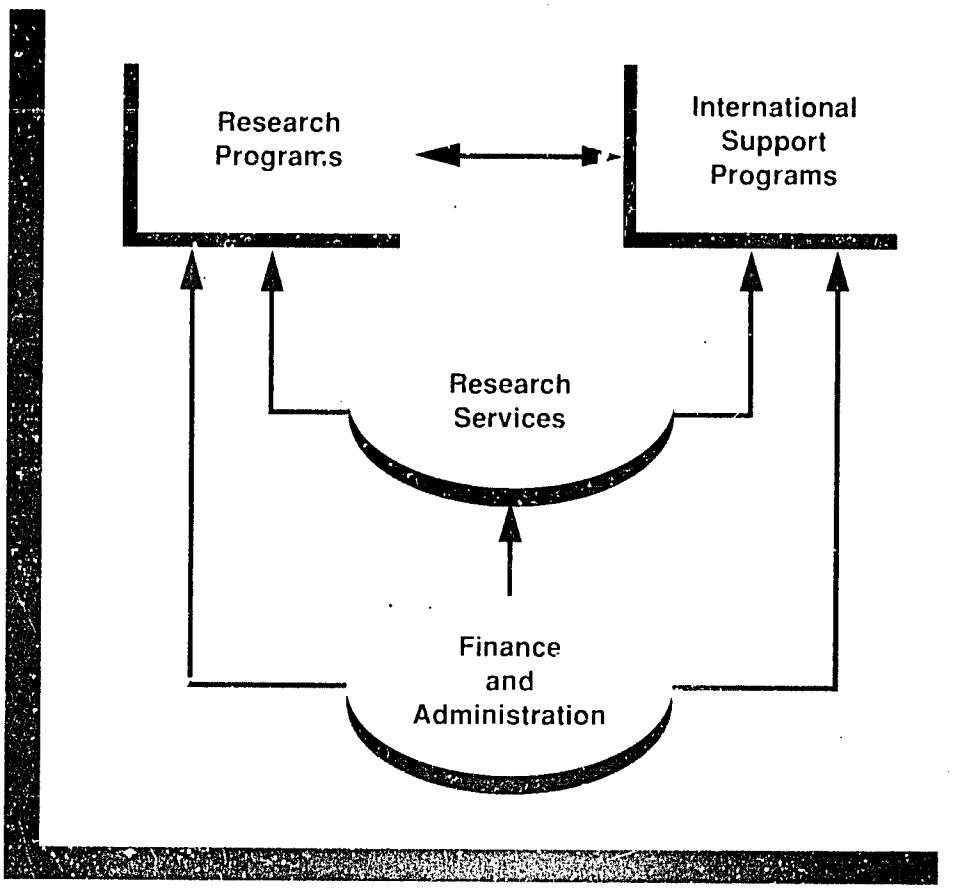


Figure 7. Functional program structure.

research data will be done in research programs but publication and dissemination of research data is an international support program. The functional program structure is intended to show how our activities will be oriented toward the strategic priorities; it does not represent an organization chart.

The research programs will be implemented through a matrix, with the five programs on one axis and discipline-based divisions on the other (Fig. 8). The research programs constitute the instrument that will set the agenda for the Institute.

The international support programs will be implemented through interdivisional teamwork. Some, such as germplasm conservation and dissemination and information and knowledge exchange, will be the primary responsibility of one or two divisions. Others, such as training, networks, and technical support, will be closely linked with the research programs and will require inputs from many divisions.

The research services will be reorganized for greater efficiency, according to the needs of the new program structure. They will include such functions as laboratory analyses, experimental farm, and controlled environment facilities.

Research program	Discipline-based division				
	1	2	3	- - -	n
1. Irrigated rice ecosystem					
2. Rainfed lowland rice ecosystem					
3. Upland rice ecosystem					
4. Deepwater and tidal wetland rice ecosystem					
5. Cross-ecosystem research					

Figure 8. Research program matrix.

The program structure and research program matrix incorporate the capability to control and direct the main resource allocation choices. Important features include the following:

- The research programs and the international support programs relate closely to IRRI's two objectives: conducting research and helping to enhance national rice research systems.
- The four main ecosystems are separately defined as the first four programs in the research program matrix. The cross-ecosystem research program is for research relevant to more than one ecosystem.
- Project funding will enable monitoring of strategic research in all the programs.
- Project funding will facilitate close monitoring of the allocation of resources to the three main regions of the world.
- Project funding also will allow monitoring of the balance of research effort between securing yield gains and seeking new yield potentials.

Matrix management

We have no illusions about the problems of using a two-dimensional framework to manage the multidimensional complexities of mission-oriented research. Several points should be noted.

First, the boundaries of scientific disciplines are not rigid: there is considerable interface between agronomy and soil science, plant physiology and plant breeding, and economics and all the other disciplines. The research programs will overlap similarly. Classification of a research project into a particular program may not be easy. For example, development of a better rice thresher could be classified under the irrigated rice ecosystem, where it is currently most needed, or it could be classified under cross-ecosystem research, since the output also can be used in other ecosystems.

Second, we are not obligated to fill every cell of the matrix nor is it mandatory that all projects involve several disciplines. This will be particularly relevant for strategic research, where we may need to focus a critical mass of resources on a project within one disciplinary division.

Third, it has been argued that some areas of great promise lie on the boundaries between scientific disciplines. Such areas may receive insufficient attention when scientists probe more deeply into their particular areas of specialization. The proposed structure will facilitate creative and interdisciplinary exploration across these boundaries, increasing the chances of breakthroughs.

The research program matrix has the potential to be an efficient mechanism to draw upon the range of disciplines needed to fulfill the objectives of each program. However, the matrix does not automatically ensure effectiveness. Clearly focused program objectives and good program and division leadership are necessary. Program leaders will be required to stimulate the enthusiasm, loyalty, and cooperation needed for effective interdisciplinary teamwork. They will be responsible for program planning, budgeting, monitoring, and evaluation. Division leaders will be responsible for maintaining scientific quality and enriching the disciplinary knowledge base. They will contribute to career planning, recruitment, and performance evaluation of scientists and will establish and maintain links with other research institutions, particularly those conducting basic research.

Lines of authority and division of labor between program and division leaders will be clearly defined. Job descriptions and evaluation will correspond to lines of authority and to the needs of effective research programming. Procedures and paper flow will be kept as light as possible, consistent with adequate financial control and accountability. The system will evolve with flexibility and with growing understanding and sense of ownership by the entire staff.

The system will be phased in, since for logistical, financial, administrative, and other reasons it is not possible to introduce it overnight. Over about two years, as a certain amount of evolution occurs, decisions on the finer details will

be made. For this reason, the column headings in Figure 8 indicating the number and nature of divisions are as yet unspecified.

Initially, for the five-year plan, a limited number of subprograms will be defined within each of the research programs described in Chapter IV. As part of this process, projects—the basic building blocks of subprograms—will be formulated. During the first and second evolutionary years, the number of projects will be kept deliberately small with each project relatively large. They will be derived from the goals and objectives of each research program.

Research projects will have clearly defined, measurable objectives, inputs, and outputs; specified time periods for implementation; and criteria for measuring success. There will be scope for midcourse correction, if monitoring reveals that is needed. Responsibility for project administration will be delegated from program leaders to project leaders, bringing managerial authority closer to the research activities and accountability closer to the users of funds. We will establish a new system for review of programs and divisions that will include peer review as well as other monitoring techniques.

Resources

IRRI's current accounting categories do not correspond to this new programming system. However, as the restructuring evolves, revised budget categories will provide accurate data for monitoring. We will aim for the following budget ratio: research programs, at least 55%; international support programs, 20-25%; research services, 10-15%; and administration and finance, 10-12%.

Quantitative allocations can be useful in monitoring the spirit of strategic intentions. However, qualitative monitoring will be equally important. Many of the strategic shifts that IRRI will make are better described in terms of what will be done and how it will be done, rather than how much will be spent. For example, one of the most significant changes in IRRI's environment is the increasing strength of national rice research systems. Many of them now expect quite different services from and relationships with IRRI than they did even 10 years ago. Thus, our international support programs, particularly in information and knowledge exchange, are likely to require more resources and will certainly change in nature as the range and degree of collaboration, facilitating, and clearinghouse functions increase. In the future, some research program components may be contracted out to institutions with the relevant comparative advantage.

We plan to centralize many services and corresponding facilities, including establishing a central service laboratory, to support the research programs and to achieve savings in the amount of resources allocated to research services. Such a shift will directly strengthen our research activities.

Within the research programs, the principal changes in emphasis will be a significant decrease in adaptive work and a reduction in some applied work, particularly when its applicability is likely to be limited to small areas. There will be a corresponding increase in some areas of applied research and in strategic research. The less favorable ecosystems will receive greater attention. We are setting 35% of research program resources as the target for allocation to the cross-ecosystem research program. More detailed estimates of the resource allocation among programs will be given in the five-year plan.

Within the international support programs, national rice research systems with special needs (e.g., in Indochina and Africa) will have priority. IRRI also has a special obligation to the development of the national rice research system in its host country and special effort will be devoted to assisting the Philippine Rice Research Institute (PhilRice).

As progress is made in these areas, the technical support component of international support programs will decline and other components will increase. This flexibility is a comparative advantage of the CGIAR system and we will use it to make the adjustments needed for effective programming.

Staff

Effective implementation of this strategy will require changes in the way scientists work, in the disciplinary mix of the Institute, and in the terms and conditions of staff tenure. IRRI will become a leaner institution, with reorganization aimed at making better use of a limited number of scientific person-years.

To be consistent with a shift upstream, scientists will need to work more interactively with other advanced institutions. The move to more interdisciplinary programs and projects will require increased teamwork within IRRI itself. An increase in on-site collaboration with fellow scientists in the national programs will accompany the shift to the less favorable ecosystems. Program leaders will need research management skills, including the ability to see what needs to be done in the research program as a whole as well as the ability to conduct research themselves.

Some changes in the disciplinary mix can be identified in general. For example, to remain in the forefront in specialized scientific areas, critical masses of scientists may be needed in such areas as microbiology and plant physiology.

Various options (e.g., fixed-term hiring and early retirement) are being considered as means to increase efficiency and acquire new skills. Some areas may be strengthened by transferring vacant positions from other areas. We recognize, however, that scientific quality and productivity are related to an individual's sense of security and confidence. All options are being explored sensitively and will be introduced with care, within a commitment to change within the next five years.

In-service training programs are being developed to redirect human resources in line with expected changes in programs, management, budgeting, and operations.

Finance

Some 29 donors contribute to IRRI's core and special programs. Funding for 1988 amounted to US$36.3 M, including that for special projects (Table 3). US$17.4 M (63%) of the US$27.7 M core budget is restricted. The Institute is making every effort to increase the level of unrestricted funding, to provide the degree of flexibility upon which a successful change in strategic direction depends.

Major changes are underway in the budgeting, accounting, and management information systems, in response to the planned organizational changes. The new systems will provide information needed for decisionmaking, as well as for monitoring, evaluation, and control, in a timely fashion. That also will ensure a flow of information to all levels within the Institute.

Facilities

Most of the physical facilities at the Institute were built in the early 1960s. Maintenance costs are increasing. Upgrading of research, laboratory, and operating equipment is critical for future operations.

A preliminary estimate of the costs of repair, replacement, and renovations includes items such as water, electricity, and fire control systems; reroofing of houses; greenhouses; vehicles; and the pesticide residue laboratory. The Institute receives 25,000 visitors a year and needs an information center to cope with that volume and to reduce the burden of visitors on scientists. A central service laboratory is planned, so that specialized equipment can be used efficiently and maintained properly. In all, approximately US$20 M will be required over the next five to seven years.

Details of costs and future physical resource requirements will be provided in the five-year plan.

Table 3. Financial support to IRRI in 1988.

Type of funding	US$ (M)		%	
Core	27.7		76	
Unrestricted		10.3		37
Restricted		17.4		63
Special funding	8.6		24	
Total	36.3		100	

IRRI's perspective

These changes must be implemented with careful study and preparation, if we are to retain and enhance IRRI's comparative advantage in disciplinary depth. This will require extensive dialogue within the Institute, assisted by a systematic, module-based, in-house training program tailored to the needs of the new organizational units and the IRRI staff. Research—the first purpose of the Institute—must continue during the changeover period. We must budget enough time to ensure that this will happen and that the reorientation and adaptation process is indeed helping us enhance IRRI's contribution to the goal:

> *Improved well-being of present and future generations of rice farmers and consumers, particularly those with low incomes.*

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The International Rice Research Institute Mandate

(as amended 14 October 1982)

The purpose of the Institute is to establish, maintain and operate an international rice research institute designed to pursue any and/or all of the following objectives:

1. To conduct research on the rice plant, on all phases of rice production, management, distribution and utilization with a view of attaining nutritive and economic advantage or benefit for the people of Asia and other major rice-growing areas of the world through improvement in quality and quantity of rice;
2. To publish and disseminate research findings and recommendations of the Institute;
3. To distribute improved plant materials to national, regional, and international research centers where they might be of significant value or use in breeding or improvement programs;
4. To develop and educate promising young scientists from Asia and other major rice-growing areas of the world along lines connected with or relating to rice production, distribution and utilization, through resident and joint training programs under the guidance of well-trained and distinguished scientists.
5. To establish, maintain and operate an information center and library which will provide, among others, for interested scientists and scholars everywhere a collection of the world's literature on rice;
6. To establish, maintain and operate a rice genetics resources laboratory which will make available to scientists and institutions all over the world a global collection of rice germplasm;
7. To organize or hold periodic conferences, forums, and seminars, whether international, regional, national or otherwise, for the purpose of discussing current problems and for developing research strategies for elevating and stabilizing rice yields under different environments.

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Acronyms used

IARCs	**International agricultural research centers**
CGIAR	**Consultative Group on International Agricultural Research**
CIAT	International Center for Tropical Agriculture
CIMMYT	International Center for Maize and Wheat Improvement
CIP	International Potato Center
IBPGR	International Board for Plant Genetic Resources
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
WARDA	West Africa Rice Development Association

Other international, regional and national research centers and programs

AVRDC	Asian Vegetable Research and Development Center
ICA	Instituto Colombiano Agropecuario
ICLARM	International Center for Living Aquatic Resources Management
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	International Council for Research in Agroforestry
IFDC	International Fertilizer Development Center
IIMI	International Irrigation Management Institute
INTSOY	International Soybean Program
IRAT	Institute for Research in Tropical Agriculture
PHILRICE	Philippine Rice Research Institute
SPAAR	Special Program for African Agricultural Research
WCED	World Commission on Environment and Development
WINROCK	Winrock International Institute for Agricultural Development

Definition of key terms

rice ecosystems - broad sets of rice growing conditions, characterized in terms of water regime, chosen as the focus for programs: irrigated, rainfed lowland, upland, and deepwater and tidal wetland.

environments - a general term for the variety of rice growing conditions that prevail within the four main ecosystems, especially "favorable" and "unfavorable" conditions, and the general physical and biological setting for agricultural production.

goal - the ultimate purpose that guides the activities of an organization/program. It can be attained only by the concerted activities of a number of agencies and elements, not solely by the efforts of a single organization/program. It includes identification of the target beneficiaries.

objectives - what an organization/program aims to produce through the use of its own resources as its contribution to reaching the goal. Objectives are end-products as far as the organization/program is concerned; they must be combined with factors and knowledge outside the control of the organization/program in order to achieve the goal.

mandate - what an organization is empowered by legal or constitutional authority to do.

national rice research systems - the aggregate of science and technology institutions (including universities, NGOs, and the private sector) and their activities related to rice research in a given country (also used are "national programs," "national rice research programs," "national systems").

research levels - the types of research activities being undertaken.

- Basic research (OECD 1979) is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, with no particular application or use in view.
- Strategic research selects, evaluates, and develops from available knowledge and emerging concepts tools to solve existing and anticipated applied research problems. It links basic and applied research.
- Applied research (OECD 1979), also original investigation undertaken to acquire new knowledge, is directed primarily toward a specific aim or objective, toward resolving a particular problem.
- Adaptive research is systematic work that draws on knowledge gained from applied research to produce new materials, products, and devices and to adapt existing technology to specific circumstances.

The shift from applied to strategic research is often termed "moving upstream." Thus, the term upstream does not describe a level of research but the direction of movement along the continuum.