PA-AAE-743

IRRI Strategic Planning Committee Report

MAY 1987

The International Rice Research Institute
P.O. Box 933, Manila, Philippines
Los Baños, Laguna; Philippines

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Submitted to the IRRI Board of Trustees
May 1987

Preface

During 1984-85, the Consultative Group on International Agricultural Research (CGIAR) undertook several reviews concerning both the impact of the system as a whole and the impact of specific components of the system (such as financial management). In addition, the Technical Advisory Committee (TAC) of the CGIAR undertook an intensive study of priorities for international agricultural research and training in the CGIAR system.

The findings and recommendations of the TAC study were discussed at several CGIAR center meetings during 1986 (in Washington, Bellagio, and Ottawa). A major conclusion of those discussions was the need for each international agricultural research center (IARC) to review carefully its research priorities and strategies, based on the changing needs and strengths of national agricultural research systems (NARS), on the one hand, and on the desire of CGIAR members to accord high priority to economically underprivileged farmers and ecologically disadvantaged areas, on the other.

The Board of Trustees of the International Rice Research Institute (IRRI), at its March 1986 meeting, approved my recommendation , that IRRI should initiate a strategic planning exercise to determine the future priorities of the Institute. My recommendation was made because it was felt that changes in the strategy of the Institute were necessary for its work to conform more closely to TAC and CGIAR priorities.

IRRI's planning exercise began in April 1986 with the appointment of an Institute-wide Strategic Planning Committee (SPC), supported by a series of task forces to address specific topics. The first draft of the SPC report was furnished to the Executive Committee of the Board for their information and comments in August 1986. The second draft, which incorporated the comments of the Executive Committee and IRRI management and scientists, was reviewed by the IRRI Board of Trustees and again by IRRI senior staff in October 1986. A third revision incorporating the suggestions of the Board and IRRI management and staff was used as a basic document for the internal program review in February 1987 and was read by the External Program Review and External Management Review panels. This final document differs from previous drafts in four respects:

a. Priorities identified by the SPC have been summarized in the preface.
b. A proposed goal statement for IRRI is re-introduced.
c. The presentation of the Institute's perspective on environmental impact assessment has been strengthened.
d. The document has been edited for consistency and style.

This report has been widely debated among IRRI staff and represents the consensus of the SPC concerning IRRI's future role and priorities. The SPC also benefited from comments and suggestions given on early drafts by scientists of national agricultural research programs in several major rice-producing countries. However, it is a committee report. While the Board of Trustees has commented on drafts, no action on the report as representing Institute policy has yet occurred.

PRIORITIES IDENTIFIED BY SPC

The Strategic Planning Committe (SPC) had four major goals:

1. To review IRRI's ongoing research and training programs in the context of current goals of the CGIAR, as articulated in the TAC goal statement and priorities paper.
2. To examine how the major areas of research in which IRRI is currently involved could be consolidated to bring about greater interdisciplinary interaction and problem solving focus.
3. To review how IRRI could further strengthen its capacity to tap upstream research capabilities for solving downstream problems.
4. To examine methods of strengthening collaborative research and training activities, involving national agricultural research systems

(NARS) and universities of rice growing countries in these activities, in order to seek solutions to problems (such as unfavorable climatic and soil environments) which cannot be handled effectively at Los Baños.

Features of the SPC Report that relate to these issues are:

- Proposed Program Area (PA) 300 is designed to address issues specifically related to the *ecological and economic sustainability* of new technologies. While work on production impact and, to some extent, livelihood impact has been in progress almost since IRRI's inception, through constraints and consequences projects, research problems relating to ecological sustainability will now receive attention. We feel that one useful contribution IRRI can make in this area is in arousing awareness of sustainability issues among NARS.
- Currently, IRRI's nine major research program areas, with numerous subprograms, are:

  100 Genetic Evaluation and Utilization
  200 Control and Management of Rice Pests
  300 Irrigation Water Management
  400 Soil and Crop Management
  500 Climatic Environment and Rice
  600 Constraints on Rice Yields
  700 Consequences of New Technology
  800 Cropping Systems
  900 Machinery Development and Testing

  SPC has tried to consolidate the nine program areas into three major areas of research, with 23 subprograms:

  PA 100 Germplasm Improvement
  PA 200 Crop and Resource Management
  PA 300 Socio-Economic and Environmental Impact

  We feel that fewer, well-defined research areas will help to promote better coordination, resource concentration, and priority setting. They will help to harness disciplinary depth for solving interdisciplinary problems. We propose to set priorities in each PA on the basis offive major rice-growing environments— irrigated, rainfed lowland, upland, deepwater, and tidal wetlands. Priorities among the environments will be based on IRRI's strengths and capabilities. IRRI's current major strength is in irrigated and rainfed lowland rice research. For the other environments, research should be organized in collaboration with an appropriate NARS representing an epicenter of the specific environment.
- IRRI has already established active leadership in biotechnology research applied to distant hybridization. Better facilities now exist. The Rockefeller Foundation-funded genetic engineering network provides unique opportunities for partnership with some of the leading scientists in the world. IRRI now has excellent facilities for basic and strategic research on plant diseases. Advanced agronomic research, in collaboration with ACIAR, is in progress. Therefore, the SPC felt that IRRI has the capacity, the need, and the opportunity to move upstream in selected areas of science. Only if, in addition to performing its meaningful support role, IRRI also maintains its intellectual leadership will NARS continue to consider IRRI the pacesetter and path breaker.
- IRRI must maintain its leadership in and through partnerships. New avenues of partnership with advanced laboratories and universities, on the one hand, and with developing NARS, on the other, will have to be promoted. Without such partnerships, it will not be possible to do justice to the diverse environments under which rice is grown.

The SPC Report was produced by IRRI scientists possessing intimate knowledge of the research problems facing the rice world. The report deliberately refrains from precise priority setting within each program and subprogram area. Once the broad contours of research goals and priorities are set by the IRRI Board, with reference to recommendations of the External Program Review panel, it will not be difficult to establish precise priorities based on four criteria:

- Is the problem to be tackled extensive enough to be designated as a regional or international problem for rice improvement?
- Could a NARS handle the problem more economically and effectively than IRRI?
- Is the problem of sufficient complexity that IRRI's current advantage in developing collaborative research relationships with advanced institutions and with other international centers is an asset in its solution?
- Does solving the problem require interdisciplinary research?

One of IRRI's great strengths is its ability to generate teamwork in solving field problems.

Apart from carrying out research on problems of relevance to the rice world, IRRI provides important services, including germplasm conservation and collection. In addition, its education and communication programs are of immense value to rice research workers in NARS. These programs have been designated PA 400. Guidelines for IRRI's interactions with upstream institutes and NARS, as well as the functions of the Global Research Services, are covered in PA 500, International Collaboration. The Research Support Services available to IRRI scientists and our collaborators in NARS are designated PA 600.

The SPC document, as a product of consolidation and concentration of programs and resources, should provide an excellent basis for priority setting. It represents a model of strategic planning that utilizes the intense interactions among scientists who live and work with the realities of the rice producing — and consuming — world.

M. S. Swaminathan

M. S. Swaminathan
Director General

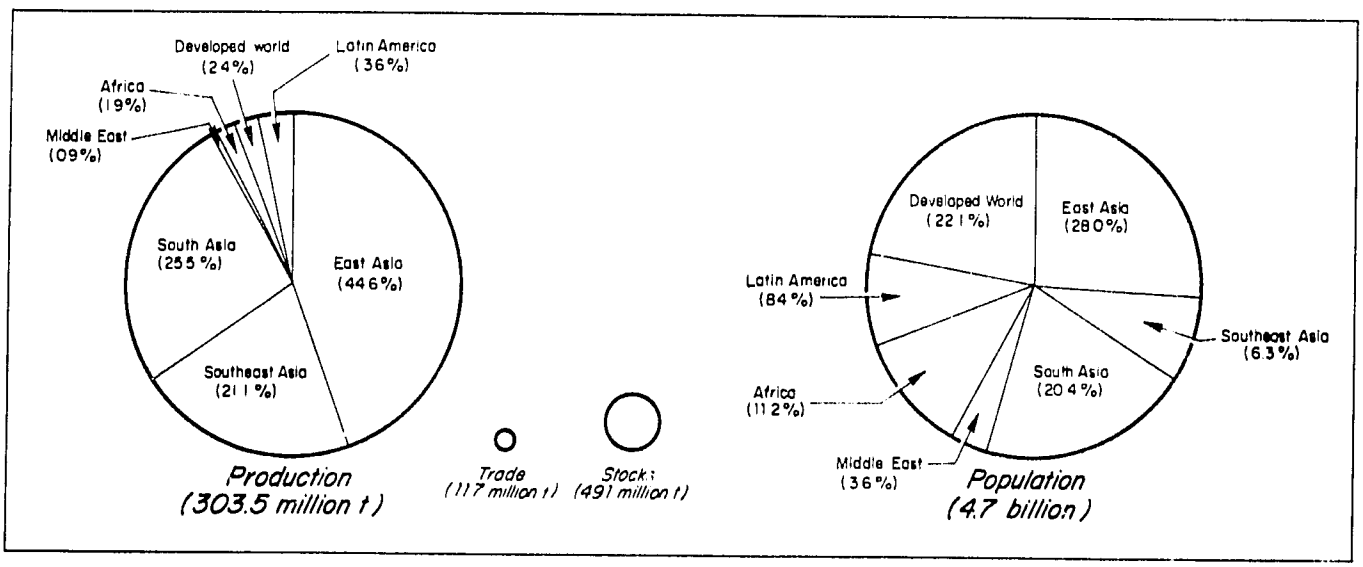
I. IRRI's Perspective

The International Rice Research Institute (IRRI) is the oldest of the agricultural research institutes supported by the Consultative Group on International Agricultural Research (CGIAR). When incorporated in 1960, IRRI concentrated its efforts on increasing the yield of irrigated rice and on training. In recent years, increased resources have been directed toward improving the yields of rainfed, upland, and deep water rice, and toward developing rice-based cropping systems.

IRRI is located in and focuses on Asia. About 90% of the world's rice is produced and consumed in this region, which also has the largest proportion of the world's population and the largest proportion of the world's poor and malnourished people (Fig. 1). IRRI also cooperates with the International Institute of Tropical Agriculture (IITA), the West Africa Rice Development Association (WARDA), and the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT) in Africa and with the Centro Internacional de Agricultura Tropical (CIAT) and Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) in Latin America. In response to both CGIAR's and IRRI's growing concern for Africa, during the last five years IRRI has expanded its intake of African scholars, commenced a cooperative country program in Madagascar, and located a Representative for East Africa in Tanzania.

It is not the purpose of this report to examine IRRI's contribution to science, training, or rice production documented in IRRI Annual Reports, reviewed by the Technical Advisory Committee (TAC) Quinquennial Reviews of 1975 and 1982, and most recently discussed by the CGIAR (Anderson et al 1986) and the Institute (IRRI 1985) at the time of its 25th Anniversary. The purpose of this report is to initiate discussion on IRRI's future as it plans its strategies for the 1990s and beyond.

IRRI must plan its future strategies in the light of those areas where it has a comparative advantage, and in the light of resources available. TAC projects that there is little scope for IRRI to expand its staffing levels, except through special projects. Therefore, the Institute's capacity to respond to new initiatives must be met largely through the redeployment of existing resources. There are now



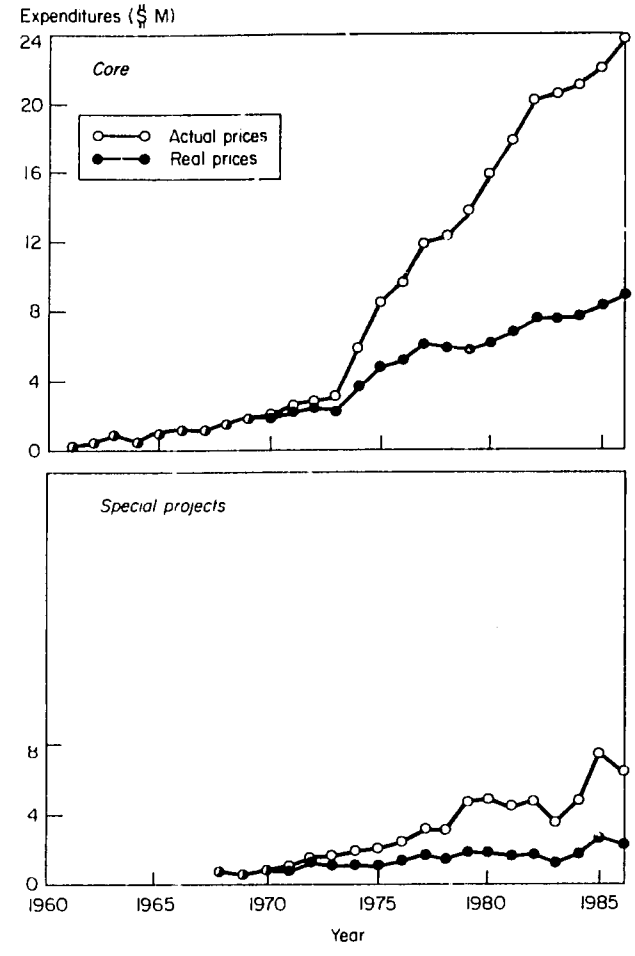
1. World rice production, trade, and stocks (1983-86) compared with world population (1984). Less than 5% of global production is traded internationally; stocks represent about 15% of production.

7 directors (4 scientific, 3 administrative), 63 senior scientific staff positions, and 4 administrative and management positions approved by IRRI's Board of Trustees and TAC. Fifteen senior staff are stationed in sister institutes and national rice programs, 4 are core/restricted core positions, and 11 are special project funded. There are 9 senior scientific staff located at IRRI headquarters on secondment from other institutes, such as CIRAD, OSTROM, IITA, and IFPRI. At any given time, 40-45 visiting scientists and postdoctoral scientists and up to 150 MS and PhD students are actively contributing to IRRI's research and training programs. As of January 1987, IRRI junior staff consisted of 574 professional and supervisory employees, 160 secretarial and clerical workers, and 1,538 technicians, artisans, and craftsmen.

IRRI's core budget has increased in real terms by nearly 4% annually over the past 10 years (Fig. 2). Special project funding has been more variable year-to-year. The core budget for fiscal year 1986 was $24 million; the budget proposed for 1987 is $26 million. In view of the progress made in rice research and the increasing research capacity of national rice programs, TAC (1986) has recommended a substantial reduction in the relative allocation for rice research in the CGIAR overall core budget. TAC has recommended that rice research in Asia remain at current levels, at least in the near future.

At its March 1986 meeting, the IRRI Board of Trustees endorsed the establishment of a Strategic Planning Committee (SPC) by the Institute to develop a discussion paper on IRRI's future strategies. This major review does not imply that IRRI's programs have stagnated; they have continuously evolved over the past 26 years in response to emerging issues, demands, and opportunities. A similar major review was commissioned in 1976 (IRRI Long Range Planning Committee Report 1979), which, after review by the Quinquennial Review Panel in 1982, acceptance by the IRRI Board of Trustees, and endorsement by TAC and CGIAR, was published as *A Plan for IRRI's Third Decade* (IRRI 1982).

Although there have been reviews in the past, the current one is timely. TAC has questioned the level of resources that should be devoted to rice and the world rice scenario is substantially different now than when IRRI was established in 1960. Also, new procedures for determining the basic core budget of IRRI on the basis of a careful determination of priorities are being introduced by TAC, based on the recommendations of the Clifford Report (1986). Under this system, research programs are classified as essential, desirable, or not essential.



2. IRRI core (1960-86) and special projects expenditures (1968-86). Constant prices based on 1967 prices. IRRI has been experiencing continued budget growth, but anticipates that its budget is less likely to grow in real terms in the near future. Its future strategy is being planned with this resource ceiling in mind.

The Institute has focused on seven points as it plans its future strategies:

- Assessing priorities in rice research and training in the context of food needs at the beginning of the 21st century and the overall goal of the CGIAR.
- Collaborating with national programs in the context of their changing needs and strengths.
- Collaborative research with advanced research institutions and universities.
- Research on resource management, with a view to promoting the economic and ecological sustainability of improved technology.

- Application of advanced research techniques and decisions on priorities in developing in-house expertise in upstream research.
- IRRI's role in Africa.
- Organizational and management aspects in relation to achieving greater efficiency and economy in IRRI's operations.

The CGIAR is currently examining opportunities to develop an integrated research and training program for rice in Africa (TAC 1986). Also, the future of WARDA is under consideration. IRRI will implement three recommendations approved by the Board pending the CGIAR decisions. They are for IRRI to: a) train African rice scientists, b) strengthen the International Rice Testing Program (IRTP) in Africa, and c) forge cooperative agreements with national rice programs in eastern and southern Africa.

The strategies of IRRI must remain consistent with the goal of the CGIAR. This goal statement, reaffirmed by TAC and by the CGIAR at its meeting in Ottawa in May 1986, is: "Through international agricultural research and related activities to contribute to increasing sustainable food production in developing countries in such a way that the nutritional level and general economic well-being of low income people are improved."

Operationally, therefore, this report was prepared, from IRRI's viewpoint, with the fullest awareness of

- The concerns of both CGIAR and IRRI to contribute to the alleviation of hunger and poverty among the poorest (rice-dependent) households, who have benefited from lower real rice prices brought about by new rice technology but who are still in need of improved means of earning their livelihood.
- The need to increase and sustain the productivity of ecologically underprivileged areas, where the poorest farm households are often found.
- The opportunities to intensify collaboration with national agricultural research systems (NARS), including the scope for assisting strong NARS to assume regional and global responsibilities for certain aspects of research and training.

This report was also prepared with a keen awareness of the changes that have taken place in the global rice scene since IRRI's establishment in 1960. This awareness, in turn, provides IRRI with the challenge and the opportunity to re-examine how it may continue to contribute most efficiently to global rice science. Seven general characteristics of the global rice scene influence the Institute's current thinking:

- The increase in the research capacity of many Asian and Latin American and some African national rice programs.
- The greater per capita rice production in most Asian and many Latin American countries, which has contributed to falling global prices of rice and other cereals.
- The inability of many national governments to assure farmers of an equitable price, as the terms of trade are against agriculture.
- The rising demand for rice on a per capita and absolute basis, particularly in Africa.
- The smaller scope for impact of modern rice technology in less favorable rice environments and the lack of, or an inadequate, infrastructure, resulting in little benefit to people living in those areas from the significant gains in food production that may have occurred at the national level.
- Inadequate purchasing power -- rather than shortage of food grains -- becoming increasingly the most important cause of undernutrition and malnutrition.
- The higher priority that needs to be given to environmentally and economically underprivileged regions and to increasing and maintaining the sustainability of crop production in the more difficult environments in which most underprivileged communities live.

IRRI'S MANDATE

IRRI's mission, as summarized in its Articles of Incorporation and By-Laws, mandates that IRRI should "pursue any, or all, of the following objectives:

1. to conduct research on the rice plant, and on all phases of rice production, management, distribution, and utilization, with the objective of improving the nutritive and economic advantage or benefit of the people of Asia and other major rice-growing areas of the world through improvements 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 to 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 that will provide a collection of the world's literature on rice for interested scientists and scholars everywhere;
6. to maintain and operate a rice genetic 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."

The mandate was slightly revised by the Board in 1982 to give greater emphasis to the global perspective, but has been changed very little since 1960.

GOALS AND STRATEGIES

IRRI will strive to respond to the mandate through an integrated program of core research and training programs and cooperative activities with NARS, universities, and other institutions. IRRI's immediate clients — and partners — are the scientists who work in national rice research programs in the developing world, particularly in Asia. Working through National Agricultural Research Systems, IRRI strives to serve the more than one billion people — more than 200 million farm families — in Asia who are dependent on rice, as a market crop and as their basic food. New production technologies help the economically underprivileged — the rural and urban poor — by enhancing rice production and sustainability, which helps stabilize and lower rice prices. Small farmers also derive benefit from rice farming system research that helps generate more on-farm and off-farm employment and income. The CGIAR goal of providing nutritive and economic advantages to farmers and consumers is integrated into IRRI's research goals and strategies.

Our goals are:

- To increase knowledge about rice and the environment within which it is grown and to provide improved materials, such as reconstituted germplasm, through research that will lead to sustained increases in the productivity and profitability of rice.
- To accelerate the pace of rice improvement through training and information dissemination that supports NARS in the achievement of their research and development goals and, as a consequence, contribute to the increased quantity and quality of food production in rice-based farming systems.

Operationally, IRRI proposes a 10-point strategy for the remainder of the 1980s and beyond:

1. Increase activities that complement and augment national rice programs. We will:
   a. involve national program administrators in determining how we can best serve national development needs as we strengthen collaboration through networks and other mechanisms in research, training, and information exchange; and
   b. collaborate with other institutions and scientists in advanced laboratories to complement the resources and capabilities of IRRI and national rice programs in developing countries.
2. Consolidate and sustain gains in rice production and productivity through research in plant breeding for insect and disease resistance, weed control, and soil fertility maintenance.
3. Develop technology to increase rice productivity under a range of rice cultures. We will seek to develop new varieties and methods that:
   a. raise the yield ceiling and increase production efficiency in irrigated and favorable rainfed areas, and
   b. provide greater tolerance to drought and flood stress and to adverse soil conditions in rainfed lowland, upland, and deep water environments.
4. Generate technology to improve the consumer and market acceptability and nutritional quality of rice varieties by seeking to improve harvesting, threshing, and postharvest handling and storage methods.
5. Analyze the effects of changes in rice production technology and policies on social, economic, and nutritional factors.
6. Place greater emphasis on natural resource

management. We will:

a. increase research to sustain the productivity of land and water;
b. conserve and share germplasm of green manure plants, biofertilizers, and biocontrol agents of pests; and
c. increase research to improve the efficient and integrated use of purchased and farm-grown inputs.

7. Collaborate with national programs to collect, further conserve, evaluate, and enhance rice genetic resources and share them with all rice scientists as a common heritage of the rice world.
8. Undertake innovative research to approach the climatically determined yield potential of the rice plant. We will apply traditional and emerging biotechnological methods of plant physiology, genetics, and plant breeding, integrated with advances in soil, crop, and water management, to attain this goal.
9. Develop, adapt, and apply problem-focused research methods, which include farmer participation, to develop socially desirable technologies for resource-poor rice farming communities.
10. Share knowledge in rice science and technology. To attain this objective, we will:
    a. concentrate on improving training programs to meet national needs, and
    b. continue scientist exchanges, publications, symposia and workshops, monitoring tours, and sharing of rice literature with national rice programs.

The changes from those strategies described in *A Plan for IRRI's Third Decade* are:

- *Sustainability*: greater emphasis on managing and conserving rice environments through crop and land management to sustain and increase the productivity of ricelands.
- *Conservation*: greater stress on genetic resource conservation, including sources of biofertilizers.
- *Biotechnology*: greater focus on biotechnology as an option to increase yield ceilings and on maintenance research to defend yield gains.
- *Postharvest technology*: increased activity in devising new harvesting, threshing, drying, and storage methods to maintain grain quality and to improve the market acceptability of rice.
- *Impact*: integrated analysis of the impact of technology on the natural environment, on production, and on the livelihood security of the poor.
- *Upstream research*: more upstream research related to the understanding of processes and mechanisms influencing rice productivity.

APPROACHES AND PRIORITIES

In examining current and future activities and priorities, the SPC recognized that:

- IRRI must continue to focus on those areas where it can play both catalytic and complementary roles of benefit to the rice world.
- The Institute's research portfolio must remain dynamic and must continuously move toward areas where IRRI can perform a valuable service or where national programs have specific needs.
- IRRI's research portfolio should have internal assessment and monitoring mechanisms to identify new research opportunities and to permit redeployment of resources through realignment of priorities.

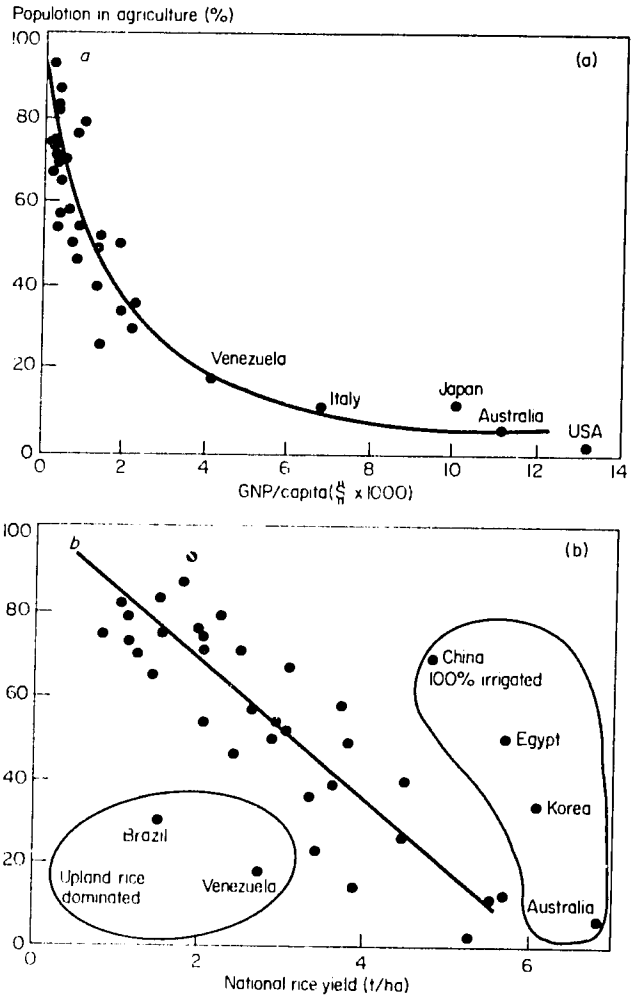
Thus, IRRI's overall strategy as it identifies its research and training programs for the next 5-10 years will be influenced by:

- The rate of development of national rice programs.
- How changes in the supply and demand for rice are matched.
- Changing social and economic goals of national programs and of the CGIAR.
- Advances in science and technology, particularly in the broad area of biotechnology.

National rice programs

The rate of development of national rice programs will depend on the financial health and resource allocation priorities of individual countries and on the success of these rice programs. Where agricultural environments are poor — often because of a combination of unfavorable resource endowments, infrastructure, and policies — the agriculture sector tends to be less productive, leading to weak economies. Weak economies, as measured in terms of per capita GNP, also tend to be associated with high dependence on agriculture for employment and with low average rice yields. Thus, the countries most dependent on agricultural growth to drive national development often have fewer and less productive resources to enable them to do so (Fig. 3).

IRRI should aim to develop strong collaborative programs with the most disadvantaged rice-pro-



3. Countries dependent on agriculture for employment tend to have lower GNP/capita (a). The most agricultural-ly-dependent countries also tend to have the lower national rice yields (b) (other than Brazil and Venezuela).

ducing countries, even though there may be low returns in terms of the effort required to effect significant changes in those areas. The major need to increase rice production and research capacity among nations that have the least resources to do so must be recognized. Any success will contribute to the livelihood security of the poorest rice-dependent populations. This implies a greater future demand for research leading to technological advances in nonirrigated environments, as countries with the lowest national rice yields also tend to be those with the least proportion of their ricelands irrigated, and consequently the lowest rates of modern variety (MV) adoption and fertilizer use.

The Institute recognizes that its partnership with NARS must be tailored to specific country requirements. This strategy was elaborated at the time of IRRI's 25th anniversary (IRRI 1985). To illustrate the need for a multiple choice approach to research and development strategies, rice--producing countries may be broadly grouped into four categories based on current average national rice yields (Table I). Clearly, in large countries such as India, there may be areas (e.g., the northwest) where Group I or II conditions prevail; other regions (e.g., eastern India) may fall into Group III or IV.

In the case of Group I countries, the greatest shared interest may be research designed to raise the yield ceiling, because, given current knowledge, there are few constraints. Thus, IRRI's major cooperation with this group of countries may be

Table 1. Classification of rice growing countries according to average national rice yields (after IRRI 1985, p. 185).

	Group I (yield > 5 t/ha)	
Australia	Egypt	Italy
Japan	Korea	USA
	Group II (5 t/ha > yield > 3 t/ha)	
Burma	China	Colombia
Cuba	Dominican Republic	Ecuador
Indonesia	Iran	Mexico
Peru	USSR	
	Group III (3 t/ha > yield > 2 t/ha)	
Afghanistan	Bangladesh	India
Malaysia	Nigeria	Pakistan
Philippines	Sri Lanka	Venezuela
Vietnam		
	Group IV (yield < 2 t/ha)	
Brazil	Guinea	Ivory Coast
Kampuchea	Laos	Liberia
Madagascar	Mali	Nepal
Sierre Leone	Tanzania	Thailand
Zaire		

Source: National yield estimates derived from FAO Production Yearbooks.

upstream research, with a resulting opportunity to adapt and transfer scientific innovations developed through this cooperation toward solving rice production problems in less advantaged countries of the developing world.

In the case of Group II countries, the need is for concurrent efforts to increase and sustain yields and to increase production efficiency by removing constraints, as has been demonstrated in Group I countries with available technologies.

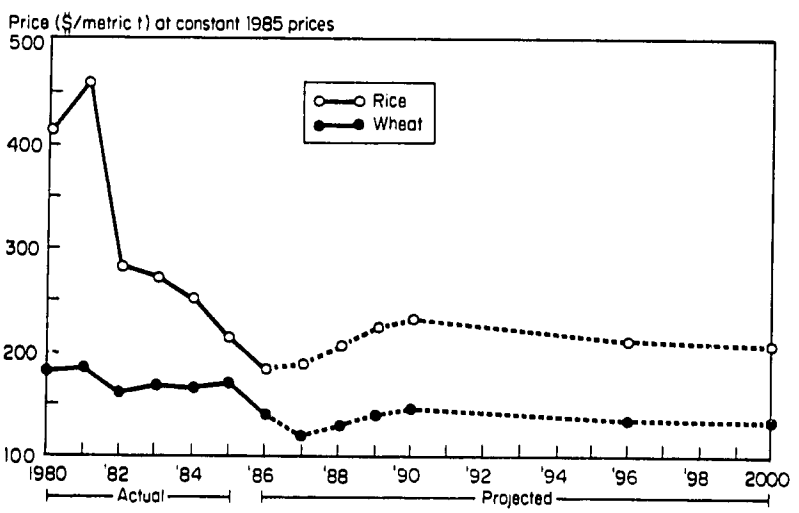
Group III countries may require more research to increase yields under unfavorable environmental, economic, and policy situations. Large areas of most of these countries are rainfed croplands that suffer from the severe water management constraints of drought and flood. There may be soil constraints, both deficiencies and toxicities, and serious pest and disease problems. Inadequacies in research infrastructure, input delivery systems, and capital availability for the modernization of agriculture also may play important roles.

Finally, Group IV countries have at present rather low national average yields and, with few exceptions (e.g., Brazil), are countries with the most unfavorable resource endowments for rice research and production. Here again, the reasons for low yields may vary (the entire rice area in some countries may fall under the category of rainfed upland). Careful studies of research areas that need attention, based upon the identification of potential impact points, will be necessary.

Matching supply and demand

The World Bank predicts that the real price of rice and other major cereals, typified by wheat, will remain stagnant in the short- to medium-term (Fig. 4). This projection is based on the fact that rice production has increased more rapidly than population, particularly in Asia, due to the success of modern rice technology, and assumes it will continue to do so. A thin world market for rice has contributed to falling international rice prices (Siamwalla and Haykin 1983). Less than 5% of production is traded internationally; a number of major, traditional Asian rice importing countries have reached self-sufficiency or near self-sufficiency (e.g., Indonesia, India, Bangladesh) and a number of new markets have contracted, particularly in foreign exchange-scarce African nations. The current low international rice price has also been exacerbated by excess production and export subsidies in a number of industrial nations and by severe foreign exchange constraints which have reduced the international purchasing power of many rice importing countries.

The concern for maintaining low rice prices, which seems to be a policy objective of most governments because of the importance of rice in the diet of the poor, has several implications for IRRI's research priorities. First, it becomes more important to seek additional opportunities to increase both the incomes of rice farmers and alternative employment opportunities in rice-de-



4. International prices for rice (Thai, white, milled, 5% broken government standard, export price, FOB Bangkok) are projected to remain stagnant, at least for the next decade. Source: World Bank Economic Analysis, Projection Department, Commodity Studies and Projects Division, 18 August 1986 Office Memorandum.

pendent regions. The roles of legumes, other cereals, tubers, tree crops, livestock, and fish in rice farming and uses of rice byproducts as part of the rice research process increase in importance. Second, rice farmers face a cost-price squeeze because, while rice prices are falling, the prices of commodities that the farming family has to purchase may not be falling. Hence, research must strive to increase the cost-effectiveness of rice technology and to increase the productivity of inputs. Third, and possibly of critical importance in the mid- to longer-term, the low rice prices projected will act as a disincentive to investment in the rice sector (e.g., in research, irrigation, and fertilizers), which in turn will increase the possibility of production short-falls and, in consequence, lead to rice price increases. Fourth, low rice prices will discourage farmers from producing more, which also will discourage adoption of technological innovations.

The thin, residual, and changing structure of the world market for rice makes forecasting future prices a hazardous undertaking. Even quite a small shortfall in rice supplies, due to unpredictable shifts in weather or in policy, would soon invalidate World Bank predictions of stagnant rice prices. It is also difficult to reconcile the Bank's price projections with those of agencies such as FAO and IFPRI. In FAO's study "At 2000," which is also the data base of the TAC Priorities Paper, projected demand for unhusked rice in the 90 developing countries which account for 98% of the population of the developing world outside China is 520Mt by 1990 and 639Mt by the year 2000. This represents a projected annual increase in rice supplies of 3% in the 1980's and 2.1% in the 1990's (FAO 1985). Both FAO and IFPRI project that the self-sufficiency ratio for rice will decline to less than 100 by the year 2000 (Table 2). Barker et al (1985), on the basis of a country-by-country examination of potential rice supply and demand, are also less optimistic about future rice prices and supply.

In short, it is unlikely that rice production will increase at a rate that will prevent increases in its real price unless there is the necessary research investment to ensure that innovations to increase rice yields are forthcoming, as well as the necessary infrastructural development. Indeed, although Africa is in the news today and is the primary focus of the CGIAR, major problems of hunger and employment may occur in Asia by the turn of the century because of the pressure of population on the land (Mellor 1984) and because of low rice prices dampening the public and private investments necessary to sustain increases in supply. The

Table 2. Commodity balances for paddy rice - past and FAO and IFPRI projections for 2000.[a]

	Production	Demand	Net Balance	Self-sufficiency ratio
	---------million metic tons---------			
FAO (90 developing countries of the world)				
Past				
1961-1965	144.5	144.4	–	100
1975-1979	207.4	209.4	- 2.0	99
Projected (2000)				
Scenario A[b]	388.9	387.7	–	100
Scenario B[c]	363.3	374.8	-11.5	97
IFPRI (20 developing member countries of the Asian Development Bank)				
Past				
1966-1970	144.7	142.4	2.3	102
1976-1980	187.3	185.6	1.7	101
Projected (2000)				
Trend[d]	309.9	327.9	-18.0	95
Low demand[e]	309.9	322.5	-12.6	96
High demand[e]	309.9	336.8	-26.9	92

[a]FAO = Food and Agriculture Organization of the United Nations, IFPRI = International Food Policy Research Institute. [b]Scenario A = with optimistic assumptions using the following percentage growth rates: population (2.4%); Gross Domestic Product (GDP) (7.0%); total domestic demand for food, feed, and agricultural raw materials (3.7%); and total production of food, feed, and agricultural raw materials (3.7%). [c]Scenario B = a modest improvement of trends with the following growth rate assumptions: population (2.4%); GDP (5.7%); total agricultural domestic demand (3.2%); and total agricultural production (3.1%). [d]Based on 1960-81 income growth trend. [e]Low and high income growth rates are based on 75 and 125 percent of 1961-80 trend GNP per capita in each country, with minimum and maximum levels of 0.5 and 6.0 percent a year. Sources: FAO, Agriculture: Towards 2000, 1981. IFPRI, Assessment of Food Demand/Supply Prospects and Related Strategies for Developing Member Countries of the ADB, 1984.

challenge is to maintain Asian rice growth rates of the recent past into the next decade. Without another breakthrough in rice technology, all the impressions of food abundance will disappear within a decade or two (Mellor 1986). Even today, there are more undernourished people in Asia than in Africa.

Until populations stabilize and rice production matches needs, Asia must continue to work to increase rice production under less favorable economic conditions than have prevailed in the past decade. IRRI will continue to work with NARS to meet this challenge.

Focusing on poor producers

An important shift in the goals of the CGIAR, and of IRRI, is an increased focus on global poverty and on improving the nutritional level and general economic well-being of low-income (rice-dependent) people. There is as much concern for equity issues, such as increasing the livelihood security of the poor, as for efficiency issues related to increasing total output.

One implication of this shift is that IRRI should respond by allocating more of its resources to those environments where the bulk of the poorer rice producers and rice-dependent rural communities are located. In general, these are the adverse rice-growing environments, where farmers have benefited little from the technological changes that swept more favorable environments. Another implication, as was previously mentioned, is the recognition that rice alone is unlikely to sustain farm incomes. Rice-based cropping systems that include upland crops and management systems that will preserve, if not enhance, land productivity must be developed to increase and sustain the productivity and income-generating capacity of rice-based farming systems.

A third implication is that IRRI has a responsibility to assist NARS in the development of technologies that can enhance the income of the rural poor, many of whom are women (and who frequently provide the bulk of the agricultural labor force). The poorer the household, the greater the need for women to have independent access to income.

This shift in focus implies a shift in resource allocation, from favorable to less favorable rice environments where production and social conditions indicate that the need for improvement is most acute. Such a shift was recognized and documented by IRRI's earlier Long Range Planning Committee (IRRI 1979, 1982) and is already occurring at the Institute. The SPC agrees that this shift in research emphasis was appropriate, but no further shift in emphasis is recommended. That is, the SPC stresses the importance of both maintenance and upstream research on favorable environments in order to elevate and stabilize rice yields in these areas which will continue to provide the bulk of the world's rice supplies.

PROPOSED RESEARCH ORGANIZATION

The SPC believes that it is advantageous to consolidate and streamline IRRI's research programs. The aims are:

- To promote closer integration and scientific management within broad areas of related research.
- To foster greater interdisciplinary research on specific problems within rice environments.

The SPC therefore recommends that the Institute's research and training program structure be consolidated into six Program Areas, as follows:

100 Germplasm Improvement
200 Crop and Resource Management
300 Socioeconomic and Environmental Impact
400 Education and Communication
500 International Collaboration
600 Research Support Services

This Report is presented in terms of these six Program Areas. The program numbers are used interchangeably with the program names to identify research areas. Brief descriptions of the proposed Program Areas follow:

100 Germplasm Improvement

This Program Area will cover all aspects of germplasm collection, conservation, evaluation, and utilization. It will include plant breeding activities for different environments, testing under the IRTP network, and utilization of tissue culture, genetic engineering, and other innovative techniques.

200 Crop and Resource Management

This Program Area complements Genetic Improvement by undertaking research on the management of soil, nutrients, water, crops, and pests in rice and rice-based cropping systems and on farm machinery and postharvest systems.

300 Socioeconomic and Environmental Impact

This Program Area will conduct (and promote) integrated studies of factors that govern and

determine the environmental, social, and economic sustainability of new rice and rice-based farming technologies. A major concern will be to provide feedback to scientists and policy makers that will help them maximize the desirable and minimize the undesirable impacts of new technology.

400 Education and Communication

This Program Area will stress both on-campus and cooperative activities in knowledge and skill sharing. The opportunities offered by advances in communication science and in computer technology for both instruction and communication will be fully utilized.

500 International Collaboration

A wide range of approaches, including the effective use of networks, cooperative research and training programs, and country projects supported by special project funding, will be adopted. In addition to improving the impact of existing research networks, attention will be given to promoting relevant upstream-downstream research networks that can help to harness "forward-edge" technologies to solve complex field problems. Leaders of national programs will be involved in determining IRRI's national support activities through collaborative planning meetings and participation in advisory committees for the networks, the Academic Council, and the proposed Research Council.

600 Research Support Services

IRRI will continue to maintain a set of facilities (e.g., the Experimental Farm, Phytotron, Analytical Services Laboratory, Seed Health Unit, and Computer Center) to support its overall research activities. While not established as research facilities in their own right, they are maintained at high professional standards and are managed and funded to adjust to shifts in services as Institute objectives change.

Program structure

The proposed structure of IRRI's research and training programs is a logical extension of earlier initiatives integrating the Institute's work in rice crop improvement within the current Genetic Evaluation and Utilization program. The GEU program is successful, functions well, and has been widely used as a model in structuring national rice improvement programs. Therefore, the SPC does not propose major changes in the organization or mode of operation of this program.

Following this GEU success, a major recommendation of the SPC is to integrate research in crop and land management more closely. The proposed program in Crop and Resource Management (PA 200) complements the Germplasm Improvement Program (PA 100) to provide IRRI the dual, integrated thrusts of crop improvement and crop management. The level of integration necessary in PA 200 dictates that a systems approach be adopted to solve significant rice production problems and to provide the knowledge, both in technology and methodology, to increase and sustain the productivity of rice in Asia.

PA 200 provides a mechanism to optimize returns to rice-based farming systems in terms of production and profits, given the resource, market, and institutional endowments of an area. The proposed program in Socioeconomic and Environmental Impact (PA 300) will provide an opportunity to analyze the impact of new technologies on the livelihood security of people and on the security of the basic life support systems of flora, fauna, soil, water, and atmosphere. In this way, harmony will be established between the short-term and long-term goals of rice development.

Program Areas 100, 200, and 300 are complementary and will clearly have some research in common. However, they approach rice research and development from different perspectives PA 300 from the effects of technology on the environment; PA 100 and PA 200 from the effects of the environment as determinants of research priorities and technology design. All three research programs share the perspective that physical, biological, and socioeconomic concerns are interlinked in problem identification and solution and in assessment of outcomes.

Education and Communication (PA 400) provides a formal mechanism to share advances in rice science among national rice programs worldwide. Training will continue to be conducted at all levels to meet the needs of different national programs. While training programs make a major contribution to the store of rice knowledge, publications, conferences, and seminars also contribute. IRRI's library has become the recognized major repository of information on rice. We propose to continue to keep a modern library available to all as the central rice information facility.

A key to IRRI's effectiveness will be the manner in which it collaborates with national rice programs and with universities and institutes with com-

plementary interests and expertise to further advance rice science. PA 500 will provide the operational mechanism to foster this collaboration. The NARS-IRRI joint research planning meetings and network activities have done much to foster, integrate, and coordinate joint research by national rice programs and IRRI.

The SPC intends that international collaboration should enter a new, expanded phase and take on added importance as IRRI

- Continues to respond to requests for cooperation in the development of national rice programs.
- Develops mechanisms to serve as a conduit for the application of recent upstream advances in rice science to solve downstream production problems faced by national programs.
- Collaborates with strong NARS to respond to regional and international demands in rice research and training.
- Seeks to establish joint research sites with NARS to conduct research in rice environments not readily found or simulated at its headquarters site.

Research scope

Research at the international agricultural research centers is classified as basic, strategic, applied, or adaptive (CGIAR 1981). These components must be mutually supportive to ensure that real problems of agricultural management and production are solved. At IRRI, the three research programs (viz., PA 100, PA 200, PA 300) are conceived of as a means to ensure that integrated research focuses on significant problems of rice crop improvement and on the management of rice-based systems. Activities in Education and Communication (PA 400) and in International Collaboration (PA 500) will ensure that advances in rice science are shared globally with rice scientists.

Basic research is designed to generate new understanding. At IRRI, such research aims to generate fundamental knowledge that can be brought to bear on several related rice-based problems. Thus, IRRI's basic research supports the strategic and applied research that applies new knowledge to solve problems that constrain sustained increases in rice production. Research on wide hybridization using the emerging techniques of biotechnology, physiological studies to increase yield potential, the development of monoclonal antibodies for disease diagnosis, and studies of insect pest-predator interactions are several examples of basic research on rice conducted at IRRI.

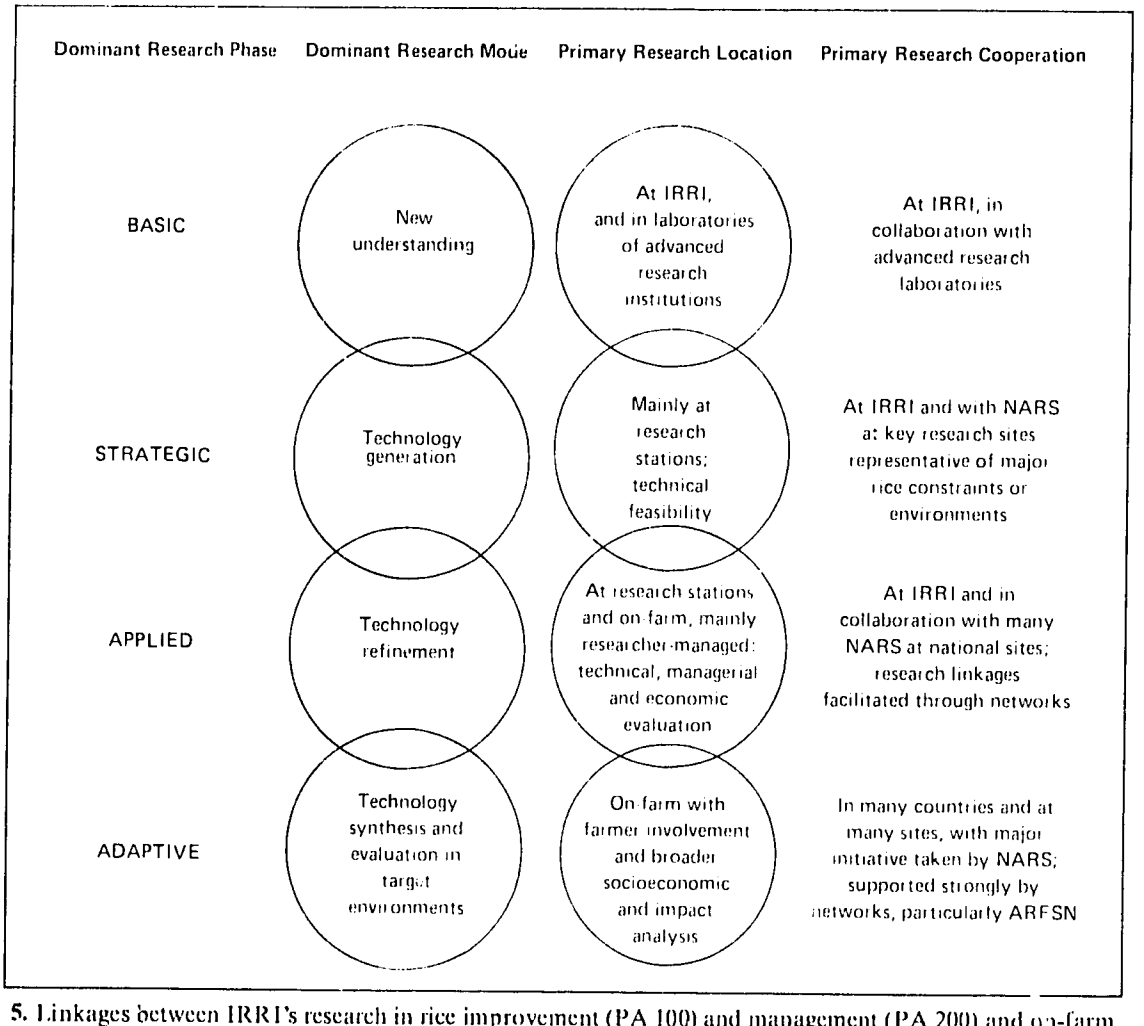
Most of IRRI's basic research is conducted at IRRI headquarters and, as described in the section on International Collaboration, is frequently done in collaboration with and sometimes at advanced research institutes with expertise on a given topic. For example, in the case of wide hybridization studies, IRRI directly benefits from collaboration with the University of Nottingham in England and Cornell University in the USA; this research is funded by a special Rockefeller Foundation grant.

A large part of the research at IRRI is strategic, in the sense that it is purposefully designed to solve specific research problems. Examples are research into breeding for stress environments and for pest resistance, into nitrogen transformations in flooded soils, and into the establishment of nonrice crops on wet, puddled soil after rice. This class of research is conducted in research-managed environments at IRRI, elsewhere in the Philippines, and, in collaboration with NARS, at sites in other countries where an issue is of widespread concern (e.g., breeding for cold tolerance in collaboration with the Chinese National Rice Research Institute and with the Office of Rural Development in Korea, or for salinity tolerance in cooperation with the Indian Council on Agricultural Research). Strategic research projects are frequently linked to and supported by basic research as is the case with nitrogen transformation experiments supported by work at the International Fertilizer Development Center (IFDC) in the USA, the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, and the Justus Liebig University in Germany.

Applied research at IRRI is designed to create new technology to address specific field problems of widespread concern. Much of the work in the management of deep water rice, soil fertility and integrated nutrient management, and integrated pest management (IPM) falls into this category. Components of this research are sometimes conducted at IRRI, but more often are conducted in collaboration with NARS at research stations and in farmers' fields (although researcher-managed), through formal (e.g., IRTP) or informal (e.g., herbicide evaluation) networks, or on a one-to-one basis with national programs (e.g., deep water research in collaboration with the Thai Department of Agriculture or IPM in collaboration with the Philippine Department of Agriculture and Food and with FAO).

Adaptive research – designed to adjust technology to specific needs or environments – is in most cases conducted on-farm, with farmer participation and with NARS taking leadership. Most of IRRI's work in technology integration that falls into this category may be orchestrated through the Asian Rice Farming Systems Network (ARFSN), the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER), and other IRRI networks, or be done on a one-to-one basis with NARS (e.g., varietal selection and research on fertility management in Bhutan and Kampuchea).

The structure of IRRI's research and training programs facilitates a two-way flow of information between IRRI and NARS scientists and between those involved in upstream (basic, strategic) and downstream (applied, adaptive) research. It also provides a mechanism to integrate research conducted in laboratories or research stations and that in farmers' fields to promote the rapid solution of field-identified problems and the adaptation and adoption of technology to solve those problems (Fig. 5). While such research is conducted mainly by IRRI scientists at IRRI and elsewhere in the Philippines under researcher-managed conditions, as research moves more downstream, it is typically conducted collaboratively with NARS scientists at a range of research sites, with NARS scientists taking leadership in developing technology that meets the needs of their nations' rice farmers. Clearly, the combination and level of upstream and downstream research cooperation among NARS and IRRI will vary among countries, depending on their capacities and the priorities set by national development objectives.



5. Linkages between IRRI's research in rice improvement (PA 100) and management (PA 200) and on-farm evaluation. The on-farm work not only involves technology testing, but also provides feedback to the researcher from the farmer and the farm environment about technology. While the Farming Systems Program and PA 300 are concerned primarily with the adaptive, downstream phase, and the other research programs with the more upstream phase, significant overlap of activities may, and should, occur to facilitate information flow and to ensure the most rapid and efficient development and adoption of new technology.

II. Targeting Research by Rice Environment

The water regime of the rice crop is the principal determinant of varietal requirements and crop production practices. For classification purposes, five water regimes are generally distinguished: irrigated, rainfed shallow, deep water, upland, and tidal wetland. These rice environments are described in detail in *A Plan for IRRI's Third Decade* and in IRRI (1984). The major categories are divided into several subcategories on the basis of hydrologic, climatic, and soil determinants of rice production.

The approximate distribution of rice area by environment and their relative contributions to global rice production are listed in Table 3. We stress that these figures are estimates, but the figures used to construct the table do represent the best judgment of scientists from IRRI and elsewhere of the distribution of global rice area and production. To this extent, the figures are at best indicative, and must be regarded as such. Accepting this caveat, over 70% of the world's rice is produced from the 50% of the world's ricelands that are irrigated. Irrigated land will remain the main supplier of rice in Asia and must continue to serve as the buffer for rice food security when there are production shortfalls in less favorable environments.

Rice varieties and management practices for irrigated and favorable rainfed conditions, in general, can be widely adopted. This is because soil-related differences in the factors affecting rice production are greatly reduced when the soil is flooded. Not only are differences related to water availability removed, but differences in other soil factors, such as acidity and phosphate availability, are reduced because of the chemical changes that occur when soils are flooded.

In nonirrigated conditions, either an excess and a deficiency of water may occur. The major differences among nonflooded soils usually exert their effects by creating major productivity differences among locations. Therefore, technologies for disadvantaged rice growing environments are often specific to a limited area within the environment. This is not true of technologies for favorable irrigated and shallow rainfed conditions.

Table 3. Tentative allocation by rice environment of global harvested rice area and production.

Rice environment	Harvested area (million ha)		Contribution to global rice supplies (%)
Irrigated		78	73
Wet season	69		
Dry season	9		
Rainfed lowland		33	17
Drought-prone	13		
Submergence-prone	4		
Drought- and submergence-prone	3		
No single severe constraint	6		
Medium deep (0.25-0.50 m)	7		
Tidal wetlands		5	1
Deep water		11	5
Deep (0.5-1.0 m)	6		
Very deep (>1.0 m)	5		
Upland		19	5
Long growing season, fertile soils	2		
Long growing season, infertile soils	7		
Short growing season, fertile soils	5		
Short growing season, infertile soils	5		
Total harvested area		146	

Note: These figures are estimates based on the judgment of IRRI and other scientists, and should be regarded as indicative, as opposed to precise, estimates of rice areas and production. Contribution to global rice supplies do not exactly equal 100 due to rounding errors.

The greater importance of environmental characteristics in the disadvantaged areas mandates that more attention be given this topic in the future.

A challenge facing IRRI is to combine its original objective, to contribute to increases in overall rice production, with increased attention to the productivity of underprivileged farmers, to equity issues, and to ecologically disadvantaged areas. A proper balance must be maintained between the objectives of

- Safeguarding and stabilizing overall rice production in line with the needs of a still-growing population, which requires continuing attention to irrigated rice and rice production in favorable rainfed environments.
- Contributing, through research on rice and rice-based cropping systems, to the well-being of people in less favorable environments.

Research in PA 100, 200, and 300 will be targeted by rice environment to assist in maintaining a balance between production and equity goals. Within each environment, well-defined research projects will be established. In this manner, a scientist's research within a rice environment and problem area will be definable in terms of an identifiable research project. Each project should have achievable objectives, a clear timetable, and quantifiable, recognizable outputs.

The rice environment focus within a research program area may be identified by the designation of research projects. For example, research project X Y Z would identify Program Area X, rice environment Y, and research problem Z. In this manner, each cell in a matrix of problem areas within rice environments is identifiable. Such a system would facilitate monitoring the development of technologies for each environment. Efforts must concentrate on projects in which real progress is possible.

Many areas of research cut across rice environmental boundaries. (e.g., control of rice tungro virus and blast). Many rice varieties, such as IR36, may be widely adapted to more than one environment. The principles developed in soil chemistry and physics transcend the boundaries of wetland rice cultures. Nonetheless, focusing research by rice environment enables progress in the more difficult, disadvantaged areas to be assessed and complements IRRI's earlier approach.

IRRI must be able to conduct field research at sites that are distinctly representative of those environments it intends to serve. The choice of sites to act as models for broad rice environments becomes more critical as the Institute places greater emphasis on nonirrigated and adverse soil areas, where the environmental uniformity imposed by water management is lost. Thus, careful analysis of possible sites within major rice environments and assessment of their representativeness are necessary precursors to specific site selection for research in rice improvement, management, and impact analysis. Many of the more adverse rice environments are not well represented in the Philippines. Therefore, IRRI proposes to establish specific collaborative research programs with other national programs to jointly conduct research for these environments.

Rice environments

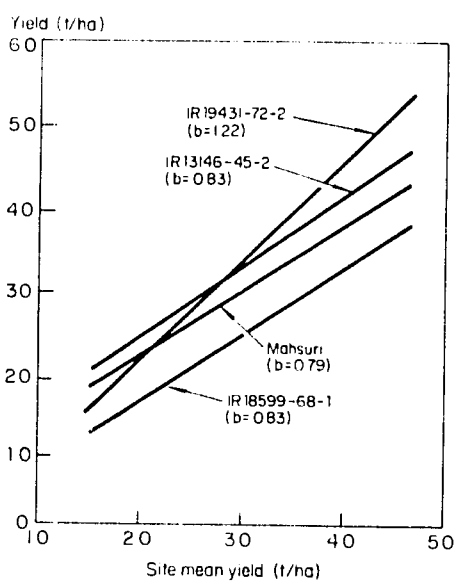
Irrigated rice. Over 50% of the world's rice is irrigated. Most of the irrigated rice crop — about 69 million ha — is grown in the wet season, with about 9 million ha grown in the dry season. China alone (which contributes 36% of the world's rice production from nearly a fourth of the world's rice area) accounts for the largest proportion of this rice environment. In the tropics, the proportion of rice that is irrigated is less than 40%. Another 5% of the tropical rice area is favorable rainfed lowland, where varieties and technologies developed for irrigated conditions are often directly applicable. The numerous improved varieties developed by IRRI and national programs over the last 25 years, coupled with improved management, were the basis of recent productivity gains in rice. Over 70% of the world's rice is now produced using modern varieties in favorable irrigated and shallow rainfed environments. In general, rice farmers in irrigated areas are economically better off than their counterparts who do not have irrigation.

Indeed, and of direct concern to IRRI, progress in improving production in less favorable areas — where the vast majority of the world's poor rice-dependent farmers, landless laborers, and rural communities are found — has been slow. The development of improved varieties and crop management techniques for these environments is a necessary condition to increasing both productivity and stability — and thereby income — of farm households and landless laborers in these ecologically underprivileged areas.

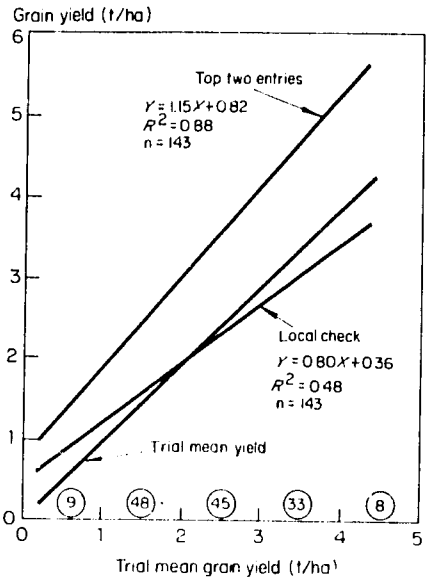
If chronically low rice prices persist, so that an investment in irrigation remains less profitable, the need to invest in research for nonirrigated areas

will increase in importance. In particular, rainfed lowland rice may require a greater share of IRRI's attention.

Rainfed lowland rice. The scope for increasing production and productivity among the four unfavorable environments is greatest in rainfed lowland. Also, the area planted to rainfed lowland rice is perhaps as large as all three other unfavorable categories put together. Many MVs that are well adapted to shallow rainfed conditions have already been developed by national rice programs and by IRRI and already are widely grown. Many of these varieties, such as IR36 and IR42, were selected from breeding lines developed for irrigated conditions, thus demonstrating the transferability of technology between these rice environments. In less favorable shallow rainfed areas (e.g., drought-prone areas) a number of lines have consistently outyielded check varieties in recent IRTP nurseries and national variety trials (Fig. 6). The performance of these cultivars demonstrates that there is a payoff to research in drought-prone rainfed lowland environments. Similarly, the adoption of Thai variety RD19 in very deep water regions demonstrates the payoff to research in flood-prone areas. About 30 million ha of the world's wetlands that are used for rice are flooded to less than 30 cm depth each year. In addition, over 100 million ha of wetlands in Africa are unutilized, with an almost equal area in Latin America. These rainfed areas may be subject to drought and to occasional serious floods that



6. Advances in breeding rice varieties adapted to rainfed shallow water conditions.



7. Regression of yields of best entries and the local check on mean yields from the International Upland Rice Yield Nursery, 1975-83. Circled numbers are number of trials.

are likely to drown the rice crop. These problems mean that yields in rainfed areas are normally lower than when irrigation is assured. The lower productivity and higher risks involved in rice production mean that farmers and credit agencies usually invest less in inputs for rice production in this environment than for irrigated rice. Nevertheless, experience in Iloilo, Philippines, and elsewhere has shown that opportunities exist for major advances in production of rice and other food crops in these areas, even when it is not possible to develop irrigation systems.

Upland rice. About 20 million ha 15% of the world's rice area are planted to upland rice. In tropical Asia alone, 11.5 million ha are planted to upland rice. In Latin America, 6 million ha 72% of the total rice area (mostly in Brazil) are planted to upland rice. West Africa has another 2 million ha of upland rice. Yields are low and prospects for major improvements are less than in irrigated and rainfed lowland environments. Nonetheless, IRRI's increased commitment to upland rice research is starting to pay off. Results of trials in recent years show that considerable progress has been made in producing better upland breeding lines for specific locations (Fig. 7). Also, in terms of equity, upland rice deserves attention. Many of the poorest-of-the-poor subsistence farmers depend on this rice environment for their sustenance. A recent survey of upland rice breeders

in 41-countries identified drought, weeds, blast, brown spot, acid soils, and phosphorus deficiency as the most critical researchable constraints to increasing upland rice productivity. Other factors that must be considered from a land management viewpoint are the problems of land degradation, low sustainability of upland rice systems, and deposition of silt eroded from the uplands on lowland rice areas and on the dams and canals that supply water to them.

Deep water rice. Deep water rice is grown on about 12 million ha globally. Some 10 million ha of deep water rice are found in South and Southeast Asia alone, in the four major river deltas – the Mekong in Vietnam and Kampuchea, the Chao Phraya in Thailand, the Irrawaddy in Burma, and the Ganges-Brahmaputra in Bangladesh and Eastern India.

There are several avenues for improvement of yield or profitability of deep water rice. On the management side, crop intensification in Thailand, through the insertion of a pre-flood, very short duration rice crop, has shown promise. Deep water rice could be grown in areas in Kalimantan (Indonesia), Mexico, Africa, and elsewhere that are now idle in the wet season. In South Kalimantan, the Indonesian Ministry of Agriculture has released three new deep water rices for this purpose, all of which resulted from cooperation in Thailand between the Thai Rice Research Institute and IRRI. This cooperation has continued since 1975. It is particularly focused on the design of improved plant types combined with elongation ability in deep water or submergence tolerance in flash floods.

RD19, released in 1979 in Thailand, is a modern variety type with elongation ability that extends its range of adaptation to water depths of 1 m. It is a well-adapted prototype of future varieties. Materials resulting from this cooperation have also been released in West Bengal, India, and in Burma.

Tidal wetland and adverse soil rice. Tidal wetlands and areas with adverse soils, such as peatlands, mangrove swamps, and acid sulphate soils, are a vast and largely unexploited land resource for rice production. Tidal wetland rice is now grown on about 5 million ha. Vast areas of tidal wetlands and problem soils – equal to more than one-fourth the currently cultivated riceland – not now used for rice production have the potential for rice cultivation, if tolerant varieties and appropriate management practices are developed. About 28 million ha in Asia alone could be economically developed.

Alternatively, expansion into the currently idle wetlands may occur as pressure on land increases, as the range of varieties adapted to adverse soils increases, and as improved understanding of soil-related problems and systems of land management renders the cultivation of rice in these lands feasible. Therefore, it is important to know the extent of these lands, to better characterize the nature of the problems, and to support varietal development and crop and land management to increase productivity. Salinity in coastal areas and in irrigated areas poses special management problems of particular concern to the International Irrigation Management Institute (IIMI); IRRI may complement that Institute's work through research on varietal improvement, problem soils, and associated crop and land management.

Benefits by rice environment

Three criteria may be considered when examining IRRI's research objectives, the weight given to each will determine the distribution and nature of the Institute's impact. First, *efficiency* considerations help identify priorities in the distribution of research funds across rice environments. Second, *equity* considerations counterbalance the first objective, because IRRI is concerned with the development of rice technology and rice-based cropping systems adapted to those regions where MVs have had the least impact. Third, IRRI is also concerned with orienting its research in line with its *comparative advantage*, resulting from the high quality of the research base in Los Baños, in solving problems that NARS are unable to address.

These three criteria are explicitly or implicitly considered in the discussions of the Program Areas that follow. IRRI's concern for equity will become more apparent when the Institute's actual and proposed allocations of resources are discussed and compared (with resource allocation based on efficiency criteria alone). The sections on Program Areas, specifically the one on PA 500, demonstrate that IRRI is operationally concerned with matching its resources to the needs of national rice programs and with ensuring that its research is complementary to that of NARS scientists.

From an efficiency viewpoint, research resources should be allocated to produce similar marginal social benefits per unit of research input in each rice environment. In the absence of quantitative data to approximate this relationship, a simpler strategy

would be to allocate research expenditures to rice environments in proportion to the value of expected benefits.

IRRI undertook such a study for South and Southeast Asia in 1980 (IRRI 1982). The SPC updated this analysis to derive estimates of the value of benefits expected from research focused on each of the major rice-growing environments. In doing so, minor adjustments were made to the assumptions of the previous study. First, small adjustments were made in current rice area by environment to bring them into line with IRRI's current terminology (IRRI 1984). A second adjustment allowed for a modest increase in rice cultivation on currently idle wetlands (5 million ha) by the year 2000. A third adjustment allowed for the expansion of dryland rice (1.2 million ha) by the year 2000; this reflects the opportunities for substantial dryland area expansion in Sumatra, Kalimantan, Northeast Thailand, Eastern India, and elsewhere. A fourth change decreased the yields of upland crops grown in rice-based systems but increased their value to acknowledge that most of these crops will be high-value grain legumes. Table 4 summarizes the underlying assumptions and estimated benefits, if the assumptions inherent in the model fairly represent the Asian rice scenario.

IRRI scientists estimated that yield increases averaging 1.2 t/ha and intensity increases averaging 0.7 crops per year are possible by the year 2000. These estimates, coupled with a net growth rate of 1.5% per year in irrigated rice and area adjustments as specified, result in a projected growth rate in rice supplies of just over 3.4% per year – slightly lower than that predicted by the Trilateral Commission as necessary to sustain per capita rice supplies. Modest as these production gains may be, when valued in terms of $100/t – which is extremely conservative, even in comparison with today's low international prices of nearly $200/t – the gross value of increased output is very large. Continued real investment in IRRI of about $25-30 million per year, plus investment in national rice programs, may generate an added value of rice in excess of $15 billion per year in South and Southeast Asia alone by the year 2000. These increases reflect yield and cropping intensity increases, given the new proportions of irrigated land, with existing inputs, policies, and institutions.

The distribution of gains among rice environments stemming from research investment (and irrigation development) may range from 2 to 32%, depending on cultural type (Table 4). The important point is that improvements in irrigated rice (57%) are predicted to dominate rice supply increases in South and Southeast Asia, assuming that the area under irrigated rice will continue to grow at 1.5% per year, as it has over the past 20 years. This growth rate may not be sustained because of low rice prices and increasing costs for irrigation development. Therefore, the model was rerun assuming 1%, 0.5%, and 0% net annual growth rates in irrigation. The contribution of irrigated rice to increased supply in South and Southeast Asia then fell to 54%, 51%, and 46%, respectively (Table 5). That is, the gains from irrigated rice continued to be about equal to or greater than those from all other environments combined. As the rate of growth in irrigated hectarage diminishes, rainfed lowlands increase in relative importance as a source of rice supplies for South and Southeast Asia. The contribution of the less favorable environments (upland, deep water, and tidal wetlands) to regional rice supplies remains reasonably constant.

It must be stressed that the estimates of rice yield in the different environments and expected benefits are very approximate. Even so, the preceding analysis demonstrates that the returns from rice research in South and Southeast Asia appear to be extremely large, and that, from an efficiency viewpoint, investment in irrigated rice should continue to be afforded priority. Indeed, there may be substantial underinvestment in rice research in Asia, given the potential gains and the size of the Asian population whose staple food is rice. We stress, as did the Long Range Planning Committee and the Board when adopting *A Plan for IRRI's Third Decade*, that these benefits will not result from IRRI research alone; they will be the product of the entire rice research system, that is, of national programs and IRRI combined. Hence, we must continue our efforts to generate greater synergy between national programs and IRRI.

The benefits from increases in productivity in East Asia, where IRRI has active programs with China and Korea, are not reflected in Table 4. Had China been included in the analysis, then the benefits from investing in irrigated rice would have overwhelmed the calculations. IRRI has a strong cooperative program with China. IRRI cultivars are widely used as parents in Chinese rice breeding programs and IRRI varieties are the most popular restorer lines used in commercial hybrid seed production.

Table 4. Estimated value ($) of gains from rice research leading to increased rice production (area, yield of rough rice, cropping intensity) in South and Southeast Asia to year 2000.

Parameter		Units	Rice culture type (000 ha)						
			Irrigated		Rainfed				Total
			1 crop	2 crop	Shallow	Deep	Floating deep	Wetland	
Present (1980)	Harvested area	(000 ha)	13641	15226	30375	11587	5290	11593	87712
	Rice yield	(t/ha)	3	3.5	1.8	1.4	1	1	
	Production	(million t)	40.92	53.29	54.68	16.22	5.29	11.59	182
	Upland crop (yield in 2000)	(t/ha)	0.5	0.5	0.3	0.3	0.3	0.2	
	Crop intensity, rice		0.9	1.8	0.9	0.7	0.7	0.8	
	Crop intensity, upland crop		0.3	0.2	0.4	0.3	0.3	0.5	
	Geographic area	(000 ha)	15157	8459	33750	16553	7557	14491	95967
In 2000	Irrigated increase (1.5%)	(000 ha)	4731	5281	-4946	-1887	0	0	3180
	Wetland check	(000 ha)	20414	11393	28255	13857	7557	14491	95967
	Rainfed increase	(000 ha)	0	0	4500	500	0	1200	6200
	Harvested area	(000 ha)	18372	20507	29929	10200	5290	12793	97092
	Geographic area	(000 ha)	20414	11393	33255	14572	7557	15991	103181
	Change in rice yield		1.2	0.9	0.8	0.8	0.5	0.5	
	Change in rice intensity		0.4	0.5	0.3	0.2	0.1	0	
	Change in upland crop intensity		0.2	0.2	0.1	0.0	0.1	0.3	
	Rice price	($/t)	100	100	100	100	100	100	
	Upland crop price	($/t)	150	150	150	150	150	150	
Change due to Irrigation	Rice (no research)	($m)	1419.37	1848.35	-890.23	-264.17	0.00	0.00	2113
	Upland crop (no research)	($m)	118.28	44.01	- 98.91	- 36.39	0.00	0.00	27
Rice Research (no intensity)	Rice-old area	($m)	1636.92	1370.34	2430.00	926.96	264.50	579.65	7208
	Rice-new area	($m)	567.75	475.29	- 35.66	-110.95	0.00	60.00	956
	Rice total	($m)	2204.67	1845.63	2394.34	816.01	264.50	639.69	8165
Intensity effect	Rice area change	(000 ha)	8165.44	5696.38	9976.43	2914.31	755.71	0.00	27508
	Upland crop area change	(000 ha)	4082.72	2278.55	3325.48	0.00	755.71	4797.38	15240
Old technology:	Value of rice, OT	($m)	2449.63	1993.73	1795.76	408.00	75.57	0.00	6723
	Value of upland crop	($m)	306.20	170.89	149.65	0.00	34.01	143.92	805
New technology:	Value of int tech	($m)	979.85	512.67	798.11	233.14	37.79	0.00	2562
Value of research + irrigation + intensification		($m)	6059	4567	5039	1421	412	784	18281
		($)	33	25	28	8	2	4	100
Added paddy production, 1980-2000		(million t)	56.34	43.52	49.88	14.57	3.78	6.40	174
Added value of rice from research		($m)	5634	4352	4988	1457	378	640	17449
		(%)	32	25	29	8	2	4	100
Added value of upland crops		($m)	424	215	51	-36	34	144	832
Irrigation effect, no research		($m)	1538	1892	-989	-301	0	0	2140
Paddy production at 2000		(million t)	97.26	96.81	104.56	30.79	9.07	17.99	356
Annual compound growth rate		(%)	4.42	3.03	3.29	3.26	2.73	2.22	3.42

Table 5. Projected distribution by rice environment of rice supply increases resulting from investment in rice research, given different net rates of growth in irrigated area in South and Southeast Asia.

	Net growth in irrigation (%)			
	1.5	1.0	0.5	0.0
Irrigated	57	54	51	46
Rainfed lowland	29	31	33	36
Upland	4	4	4	4
Deepwater	8	9	10	11
Tidal wetlands	2	2	2	2
Growth rate in rice supply (%)	3.4	3.3	3.3	3.2

Source: Derived by varying the rate of growth in irrigated area in South and Southeast Asia assumed in Table 4.

Chinese and IRRI rice scientists also cooperate on a wide range of research topics in crop management and agroeconomics; those are agreed to and clearly defined in annual Chinese Academy of Agricultural Sciences-IRRI work planning meetings.

Neither were the benefits of IRRI's contribution to rice science in Africa or Latin America included in Table 4. This imparts a downward bias to the benefits from shallow rainfed and upland rice research, since it is expected that substantial area expansion will occur in these environments in Latin America and, particularly, in Africa. One reason for not incorporating Africa and Latin America in Table 4 is that Asia will continue to dominate the rice scene in the foreseeable future. Another is that CIAT, IITA, and WARDA share responsibility for rice research within the CGIAR system for these regions.

The yield figures used in the benefit analysis were based on yield gains that researchers conservatively feel can be achieved, assuming advances in technology but no major breakthroughs in basic scientific knowledge. No attempt was made to project the benefits of basic research that may emerge, for example, from IRRI's upstream research in biotechnology. However, it is unlikely that yield gains in farmers' fields as a consequence of this research will be realized in the next 15 years (Swaminathan 1986).

Research benefits to rice vs other commodities

This analysis confirms the substantial benefits of continued investment in rice research and associated crop intensification in Asia. However, equally important from CGIAR's viewpoint is whether investment in rice research is attractive compared to like investments in other food or industrial crops or in livestock. The Australian Centre for International Agricultural Research (ACIAR) and IFPRI conducted such an analysis. Using a quite different analytical approach, they found that the benefits from investing in rice research overwhelmed investments in other commodities (Table 6).

The ACIAR model also provides estimates of the distribution of benefits from research between producers and consumers (Table 7). Developing country consumers, through lower prices, receive a substantial share (45%) of the benefits from rice research. The bulk of the remaining benefits accrue to developing country producers. However, some of the latter group also experience substantial aggregate losses as a result of rice research and productivity gains in other countries. This applies in particular to the rice producers in less favorable environments, who face lower rice prices due to rice supply increases without benefiting as much from technological change as do producers in more favorable environments.

It has become clear from SPC's deliberations that IRRI must commit more resources to formally consider the production, economic, and equity implications of research investment by rice environment and region. As it examines its research portfolio, IRRI must also consider more carefully future demand and supply scenarios for rice. Such indepth analysis which should become a continuing activity could not be completed for this report.

Table 6. The estimated present value of international benefits from research: average for all developing countries and main regions (SUS M 1983).[a]

Commodity	All developing countries	Africa	West Asia/ North Africa	America	Asia	South Pacific
Rice	658	337	401	447	1166	–
Potato	285	71	429	241	393	–
Wheat	279	57	540	283	330	–
Sugar	139	74	134	159	186	–
Maize	138	60	149	173	248	–
Sweet potato	136	68	39	142	213	–
Bananas/plantains	126	102	24	140	150	122
Pulses	124	62	102	137	213	–
Sheep and goats	68	36	91	102	99	–
Coconut	53	32	–	49	97	43
Sorghum	52	36	26	56	103	–
Groundnuts	30	24	15	29	46	–

[a]An initial unit-cost reduction of 5% from research is subsequently adjusted by the differential probabilities of success, spillover effects, and adoption potentials for the various regions and commodities, using the formula to derive the benefit estimates. Source: Davis et al 1987, Table 4.2.

Table 7. Distribution of research benefits: average for all developing countries.

Commodity	Share of benefits received by each group (%)						
	Consumers			Producers			
	Developing	Developed	Total	Developing		Developed	Total
				Gainers	Losers		
Rice	45	3	48	69	18	1	52
Potato	16	41	58	52	−3	−5	42
Wheat	22	24	46	48	−5	11	54
Sugar	31	27	58	61	−12	−7	42
Maize	16	25	41	56	−7	10	59
Sweet potato	47	–	47	55	−2	–	53
Bananas/plantains	40	5	45	58	−3	–	55
Pulses	27	9	36	71	−4	−1	64
Sheep and goats	45	31	76	51	−8	−18	24
Coconut	37	6	43	58	−1	–	57
Sorghum	24	12	35	65	−3	3	65
Groundnuts	33	7	41	63	−5	2	59

Source: Davis et al 1987, Table 4.8.

III. PA 100: Germplasm Improvement

IRRI's major and most meaningful contribution will continue to be the conservation of genetic variability in rice and its conversion into a wide range of valuable breeding materials for selection and further breeding in different rice-growing environments. Hence, the principal focus of PA 100 will be the development of improved germplasm for the major rice-growing conditions. Development of techniques and methodologies for national programs to breed improved varieties and generation of the knowledge base necessary for continued progress are integral parts of the Program Area. Through an "Upstream - Downstream Research Network" partially funded by the Rockefeller Foundation, the latest tools of molecular biology, genetic engineering, and tissue culture will be utilized to elevate and stabilize rice yields under different environments and to improve breeding methods. The training component has always been emphasized, and will continue to receive due attention. Much of the research and training work will be done in close collaboration with national rice research programs.

During the first decade of IRRI, attention was focused on developing varieties for environments with irrigation and good water control. During the second decade, development of improved germplasm for some of the unfavorable environments was initiated. These efforts were more precisely targeted at the beginning of IRRI's third decade by defining the rice-growing environments into five major categories and by organizing breeding programs for each of those categories.

The primary aims of the Germplasm Improvement Program (GIP) for the coming decades will be to:

- Stabilize and consolidate yield gains for favorable environments, intensify efforts to further improve the yield potential and grain quality of irrigated rice varieties, and reduce growth duration to increase cropping intensity and generate increased income and employment opportunities.
- Develop improved germplasm with higher productivity and yield stability for unfavorable environments to increase opportunities for employment and income generation among disadvantaged farmers.

Five interdisciplinary task forces will be established to handle varietal improvement activities for five major rice environments:

- irrigated rice
- rainfed lowland rice
- upland rice
- deep water rice
- tidal wetland and problem soil rice

Research in related disciplinary areas will be closely linked with the varietal improvement activities.

RESEARCH PRIORITIES IN SUBPROGRAMS

GIP research activities will be divided into 14 Subprogram Areas

101 Genetic resources
102 Yield potential
103 Grain quality
104 Disease resistance
105 Insect resistance
106 Drought tolerance
107 Excess water tolerance
108 Adverse soils tolerance
109 Adverse temperature tolerance
110 Rice genetics
111 Innovative breeding methods
112 Seed science and technology
113 International Rice Testing Program (IRTP)
114 Integrated GIP

Goals and research priorities for the coming decade for each Subprogram Area follow.

101 Genetic resources

Rationale. The primary mission of the Genetic Resources Subprogram Area is to conserve rice germplasm and to provide national program scientists and IRRI researchers with the seeds needed for varietal development and related research. Since 1962, more than 600,000 seed samples of diverse germplasm have been supplied

researchers, either directly or through the International Rice Testing Program (IRTP). IRRI will strive to achieve an even more effective use of the as yet unevaluated materials and unidentified genes in the collection to speed up evaluation and utilization components. Only in recent years have rice researchers and biotechnologists tapped potential sources of low input technology and exotic genes. We will provide seed samples of entire national or state collections to donors on request.

Objectives

Essential

1. Add to the germplasm collection, principally through the assistance of national programs. Wild rices will be the primary target of future collection. IRRI's role also will focus on assisting national centers in planning and in manpower development for their own collections.
2. Process all accessions into long-term storage and enter them into duplicate storage.
3. Provide scientists with materials that either have promise for specific purposes or are known to possess one or more resistance/tolerance characteristics, for further evaluation ahead of the usual schedule.
4. Implement large-scale screening of germplasm in specific "hot spots," by national scientists, as expanded IRTP nurseries, or as collaborative ventures, to broaden the scope of genetic potential as well as to collect information on genotype x environment interactions.
5. Analyze the genetic diversity, interracial relationships, and probable duplications in the IRRI collection, using statistical and biochemical means.
6. Provide technical assistance to national and regional gene banks and help increase communication among gene banks.

Desirable

Establish purified seedstocks of outstanding sources as new accessions available to researchers.

102 Yield potential

Rationale. IR8 and other MVs, when properly fertilized, produce two to three times the yields of traditional varieties. However, yields of recent releases have not increased further, although short duration MVs have higher per day productivity. An increase in rice grain yield is essential to meet increasing food demand and to better use land. The morphological and physiological traits that might be altered to enable the yield of existing rice varieties to be raised beyond 12 t/ha are:

1. Increased harvest index
   a. Increased sink size
      i. Large spikelet number per shoot with suitable spikelet size
      ii. Greater partition of assimilates to spikelet formation
   b. Increased spikelet filling
      i. Manipulation of canopy senescence
      ii. Higher percentage of quality grain
      iii. Maintenance of healthy root system
      iv. Increased lodging resistance
2. Increased biomass production
   a. Desirable canopy structure
      i. Rapid leaf area development
      ii. Rapid nutrient uptake
   b. Reduced carbon consumption
3. Increased canopy photosynthesis during entire growth period

Objectives

Essential

1. Determine the genetic variability for the above plant characteristics.
2. Study the feasibility of increasing yield potential by incorporating the above traits into improved varieties.
3. Develop effective breeding, screening, and selection methods.

103 Grain quality

Rationale. Incorporating improved grain quality and nutritional value into a variety without added farmers' inputs would benefit both farmers and consumers. Although head rice yields were improved by breeding for completely translucent, nonwaxy endosperm, some varieties, such as IR42, show extreme susceptibility to moisture adsorption stress (cracking) when overripe or overdry. On milling, precracked grains contribute substantially to poor head rice yield. Head rice yields of IR rices are still lower than those of US and Australian rices and can still be improved. A study of consumer demand for grain quality showed that percentage broken grains is an important physical factor in market quality, in addition to whiteness, translucency, grain size and shape, and aroma.

Amylose content (linear fraction of starch) is the

major factor determining cooked rice texture and a major factor in consumer evaluation of grain quality. Gelatinization temperature (indexed by alkali spreading value) and gel consistency can discriminate quality within the same amylose class. Breeding for intermediate amylose rices with intermediate gelatinization temperature resulted in IR64 and many other lines with good overall quality. New tests are needed to further differentiate among rices with similar starch properties.

Rice is the principal source of dietary protein in tropical Asia. Although heritability of protein content is low, in replicated yield trials at IRRI growth duration was negatively correlated with brown rice protein. Protein content continues to be monitored in yield trial entries to ensure that its level is at least maintained.

The achievement of self-sufficiency in rice production in many countries has led to increased demand for rices with better milling and eating quality. Our objective is to ensure reasonable and improved grain quality in irrigated and nonirrigated MVs.

Objectives

Essential

1. Develop a screening method for and a better understanding of factors affecting varietal differences in fissuring resistance (moisture adsorption tolerance) of rough rice and brown rice. Fissuring resistance should contribute to high and stable head rice yields by reducing grain cracking in overripe or overdried grain in all rice-growing environments.
2. Develop screening methods for grain quality of nonirrigated rices and for measuring the texture of cooked rices with similar starch properties. Study the effect of adverse environmental conditions, such as drought during ripening, on grain quality. Study processed rice products to provide insights into varietal differences in quality.

Desirable

1. Encourage studies on consumer demand for rice grain quality in various national programs to establish and verify breeding objectives for grain quality in each country. In cooperation with national researchers, study importer demand for export quality rices from Thailand and Pakistan.
2. In cooperation with scientists from parboiled rice-consuming countries, develop suitable screening methods for defining the quality of parboiled rice.
3. With nutritionists in other institutions, conduct cooperative feeding trials using rice and rice-based diets with experimental animals and with humans.

I04 Disease resistance

Rationale. At present, most of the work on disease resistance is focused on identifying new sources of resistance, screening segregating populations, evaluating fixed lines, and studying the inheritance of resistance. Monitoring changes in the pathogen populations of major diseases – including blast, bacterial blight, and several virus diseases – will continue. The goal of disease resistance research is to reduce the production costs of rice farmers and to maintain stable and profitable yields.

Objectives

Essential

1. Identify potential sources of durable resistance.
2. Determine pathogen variability and host-pathogen interactions.
3. Assess the merits of using innovative breeding concepts, such as recurrent selection, for developing disease resistance.
4. Develop new screening methods, including the use of molecular and serological techniques.
5. Test new screening methodologies in "hot spot" areas through collaboration with national scientists.

Desirable

1. Assess disease resistance and gene deployment strategies.
2. Develop multiline cultivars and varietal mixtures and assess their effectiveness in disease management.

I05 Insect resistance

Rationale. The goal of the insect resistance program is to provide long-term rice production stability against a variety of dynamic insect pests and insect-transmitted diseases, without adding on-farm production costs. To achieve this, we need precise methods for evaluating resistance levels and information on the mechanisms and causes of resistance, inheritance of resistance, variability in pest populations (biotypes) in rice ecosystems, and long-term effects of the manipulation of varietal resistance on pest and natural enemies populations.

Objectives

Essential

1. Improve or invent mass rearing techniques, especially for thrips, rice hispa, stem borers, and leaffolders. Evaluate the use of plant calli and chemically defined diets as supplements or alternatives to a pest's natural food.
2. Study quantitative parameters, based on pests' responses to the plant and the plant's reactions to pest establishment, to accurately determine the degrees of resistance. Moderately resistant and tolerant varieties detected by these parameters may be more effective in integrated pest management programs aiming at long-term varietal stability.
3. Identify and characterize chemical resistance factors to identify host plant-insect relationships that can serve as selective markers in breeding resistant varieties.
4. Determine the existence of biotypes of major insect species, then use these biotypes to identify new sources of resistance for breeding programs.

Desirable

Study the influence of host plant resistance on pest population growth rate, dispersal, and biotype formation rates to increase understanding of their overall, long-term effects in an insect management program.

106 Drought tolerance

Rationale. Drought occurs in all rice environments. Although rainfed lowland and upland rice are most often subject to the yield-reducing effects of drought, even irrigated rices may suffer from drought if irrigation water is inadequate.

Methods have been developed to screen rices for drought tolerance during vegetative growth, but little progress has been made in developing drought-tolerant, high yielding varieties because of complex genotype x environment interactions and difficulty in screening for critical stage drought resistance. Research on drought resistance has one major objective — to achieve higher and more stable yields in drought-prone environments.

Objectives

Essential

1. Study the physiological responses of rice to water deficit, with emphasis on effects of stress during the reproductive phase.
2. Develop and apply improved, more efficient methods of screening, selecting, and evaluating drought resistance germplasm.
3. Determine the agronomic and physiological characteristics that confer high and stable yields in drought-prone environments.

Desirable

Develop methods to evaluate the interactions among genotype, environment, and agronomic management for site-specific drought resistance.

107 Excess water tolerance

Rationale. Elongation ability and submergence tolerance are essential for rices grown in areas with excess water. Screening methods have been developed and cultivars with varying degrees of elongation ability and submergence tolerance have been identified and are being used as donors to produce better varieties for excess water areas. However, there is very little information on the physiological basis of excess water tolerance and the inheritance of tolerance.

Objectives

Essential

1. Screen breeding materials for excess water tolerance.
2. Study the inheritance of submergence tolerance and elongation ability.
3. Develop techniques for measuring degree of elongation ability without destroying the plants.
4. Investigate the physiological mechanisms responsible for excess water tolerance.

Desirable

Combine submergence tolerance with other desirable traits, such as disease and insect resistance and good grain quality, to provide genetic material for breeding programs.

108 Adverse soils tolerance

Rationale. Vast areas of land lie idle because of soil problems. On still more such land, rice is grown with poor results. Cultivars with tolerance to soil stresses (both toxicities and deficiencies) offer an opportunity for developing improved varieties with higher productivity on problem soils. That could lead to bringing additional problem soil areas under rice cultivation. The primary purpose of incorporating tolerance to soil problems into rice varieties is to reduce production costs and to achieve high, stable, and profitable yields under adverse soils conditions.

Objectives

Essential

1. Evaluate and select tolerant varieties to establish a pool of adverse soils-tolerant germplasm.
2. Identify soil factors limiting rice yields to develop more reliable screening methods.
3. Engage in collaborative studies on mechanisms of tolerance and inheritance of tolerance traits to develop better breeding strategies and more reliable rapid screening methods. Give special emphasis to phosphorus deficiency tolerance, a common stress in almost all problem soils, and to salinity/alkalinity tolerance.
4. Determine the crucial traits for adverse soils tolerance to reduce resources employed in screening.

Desirable

Evaluate japonica rices for adverse soils tolerance, especially for acid upland soils.

109 Adverse temperature tolerance

Rationale. In the mountainous regions of the tropics and in the temperate rice-growing zones of the world, cold weather and cold water adversely affect rice yields. There are also areas in the tropics where the rice crop is subjected to high-temperature damage. We have developed methods for screening varieties for low-temperature tolerance. However, very little work has been done on high-temperature tolerance. The goals of the research program on adverse temperature tolerance are to identify sources of tolerance to adverse temperatures, to facilitate the development of improved germplasm for areas where the rice crop is subjected to adverse temperatures, and to combine temperature tolerance with other desirable features.

Objectives

Essential

1. Improve techniques to screen germplasm for tolerance to adverse temperatures at the germination and seedling stages and during the reproductive phase.
2. Evaluate varietal differences for tolerance to adverse temperatures at the time of germination, anthesis, pollen germination, and fertilization.
3. Investigate the inheritance of adverse temperature tolerance.

110 Rice genetics

Rationale Our understanding of rice genetics lags far behind that of the genetics of other important food crops. The linkage maps of rice are poorly marked, and many marker genes have not been properly mapped. During the International Rice Genetics Symposium at IRRI in May 1985, a formal international organization, the Rice Genetics Cooperative, was established to encourage research on linkage mapping. IRRI has expanded research in this field under the Rockefeller Foundation-supported project on wide hybridization in rice. Cytological maps of rice chromosomes also need to be further refined. IRRI will collaborate with scientists in Japan and elsewhere to prepare better cytological maps through newer staining techniques. A molecular map of rice nuclear chromosomes has not been prepared. Twenty-two isozyme loci are known. IRRI has started locating these genes on the chromosomes through gene dosage effects in primary trisomic heterozygotes. This research will continue until all known isozyme loci are located and mapped. Cornell University has started a project in collaboration with IRRI to prepare a restriction fragment length polymorphism (RFLP) genetic linkage map of rice. It is hoped that more than 100 DNA markers will be placed on the map during the next 3-5 years. In collaboration with advanced laboratories, we are searching for transposable elements in rice for gene tagging and subsequent cloning.

Objectives

Essential

1. Further develop the linkage map of rice.
2. Complete the cytological map of rice.
3. Prepare a molecular linkage map using RFLP techniques.
4. Study cytogenetic relationships among species of genus *Oryza* to better understand their compatibility, genome homologies, and possibilities of gene transfer.
5. Continue genetic analysis of disease and insect resistance to identify additional genes.
6. Continue genetic analysis of tolerance to such soil and climatic stresses as acidity, alkalinity, submergence, and cold.
7. Support growth of the partnership among rice geneticists and cytogeneticists through the Rice Genetics Cooperative.

Desirable

1. Locate and map the isozyme loci on the linkage map.

2. Search for transposable elements for gene tagging and subsequent cloning.

Innovative breeding methods

Rationale. Most of the progress in rice breeding so far has been based on the pedigree method, the modified bulk method, backcrossing, and mutation breeding. For further improvement in yield and yield stability, we will utilize innovative breeding methods, such as hybrid rice and recurrent selection, and the emerging techniques of biotechnology, such as anther culture, somatic cell culture, wide hybridization, somatic hybridization, and gene transfer through transformation techniques. With the support of the Rockefeller Foundation, an "upstream-downstream research network" has been established to enable using the latest tools of tissue culture and genetic engineering to solve downstream problems in practical rice breeding. In addition to assisting in coordinating this network, IRRI will undertake research in the following areas:

- Hybrid rice. Experience in China, where hybrid rice is grown on 8 million ha, indicates that hybrid varieties can outyield the best conventional varieties by 15%. However, Chinese hybrids are not adapted to tropical conditions. During the last 7 years, we have developed component lines for hybrid breeding, such as cytosteriles, maintainers, and restorers, that are adapted to the tropics. We are now identifying the heterotic combinations and refining techniques of hybrid seed production.
- Recurrent selection. The pedigree method of breeding is not suitable for improving traits governed by polygenes, such as stem borer or sheath blight resistance. Recurrent selection, on the other hand, permits the accumulation of minor genes governing these quantitative traits. We now have genes for male sterility that can be utilized in male sterile-facilitated recurrent selection schemes.
- Anther culture. Anther culture techniques can be utilized to reduce the time taken to achieve homozygosity. Selection efficiency is also increased in anther culture-derived progenies.
- Somatic cell culture. *In vitro* culture techniques can be effectively utilized in generating new variability. Somaclonal variants can be selected for disease resistance and for tolerance to abiotic stresses.
- Wide hybridization. Many genes of potential value in improving rice crop productivity are present in related wild species. Until recently, these genes were not within the reach of plant breeders because of barriers to crossing and recombination. However, new techniques, such as embryo rescue and the use of immunosuppressors, have helped overcome some of the crossing barriers. Using these techniques, we have moved genes for brown planthopper resistance from *O. officinalis* to *O. sativa*. Many other useful genes exist in other wild species of *Oryza*.
- Somatic hybridization. It is not possible to obtain hybrids between rice and very distantly related species, such as *S. coarctata*, but somatic hybrids between such species may be obtained through protoplast fusion and regeneration of hybrid progenies.
- Gene transfer through transformation techniques. Crop productivity can be manipulated within the limits of the gene pools available to plant breeders. Breeders generally have had to confine themselves to the primary gene pools of a crop. However, the new techniques of molecular biology and genetic engineering are proving useful in moving genes from unrelated species to crop plants, resulting in the broadening of crop gene pools. Three techniques hold promise for application to rice improvement: electroporation, microinjection of DNA, and vector-mediated gene transfer. Rapid progress is being made in developing protocols for achieving vector-mediated gene transfer in cereals. The two components receiving major research attention are the development of vectors for monocots and the regeneration of plants from isolated protoplasts. Both fields are developing rapidly, with the likelihood of achieving transformation in cereals in the near future. IRRI will continue to encourage research in this field in appropriate laboratories.

Objectives

Essential

1. Study the problems and potentials of hybrid rice in increasing rice yields in the tropics.
2. Evaluate male sterile-facilitated recurrent selection for improving traits governed by polygenes and for breaking undesirable linkages.

3. Investigate the feasibility of selecting somaclonal variants for disease resistance or abiotic stress tolerance.
4. Use anther culture techniques to develop homozygous breeding lines and to increase selection efficiency.
5. Use embryo rescue techniques to accomplish wide crosses.
6. Investigate the feasibility of using somatic hybridization to accomplish wide crosses.
7. Evaluate somatic embryogenesis as an alternative to F_1 hybrid seed production.
8. Encourage the development of DNA vectors and other methods, such as electroporation and microinjection techniques, for transferring desirable genetic traits across sexual barriers.
9. Assist in the growth of dynamic and purposeful partnerships between upstream research laboratories and geneticists and plant breeders working with conventional techniques, to achieve a combination of approaches and techniques that can help to solve complex production problems speedily and surely.

112 Seed science and technology

Rationale. To realize the fullest genetic potential of a variety, good quality seed should be used for sowing. The seed increase program of IRTP, for example, would be greatly benefited by improved techniques for producing, processing, and storing seeds. Those techniques may also be utilized by basic and commercial seed producers in rice-growing countries, resulting in the availability of high quality seed to farmers.

Objectives

Essential

1. Standardize efficient seed production methods, including seeds of hybrid rices.
2. Standardize improved seed treatment methods for use during prestorage, mid-storage, and presowing stages.
3. Develop preharvest pest management techniques to ensure high quality seeds.
4. Investigate the relationships among level of disease infection, loss of vigor in seeds, and disease transmission to the succeeding crop.
5. Assess genetic and biochemical changes in seeds during storage under various environmental conditions, including studies on seed dormancy.

Desirable

1. Conduct "drill box surveys" in rice-growing countries to learn the quality of seed currently being used by farmers, to enable estimates of potential improvements in productivity through the use of quality seed and to identify the areas where currently available technology can be applied.
2. Assess varietal differences for seed storability and vigor so that these characters can be incorporated into high-yielding varieties.

113 International Rice Testing Program

Rationale. The International Rice Testing Program (IRTP) provides rice scientists around the world with access to a wide spectrum of varietal diversity. Moreover, it provides them with a mechanism through which their breeding lines can be tested under a wide range of agroclimatic conditions within a short span of time. Also, the program helps to identify genetic variability with respect to major insects and pathogens and the adaptability of varieties to diverse environments. It helps developing NARS to purchase time in identifying better strains for their growing conditions and helps stronger NARS to share their material with others, effectively utilizing a global gene pool in their breeding programs. IRTP also helps to identify "hot spot" locations for screening for pest resistance and soil stress tolerance.

Objectives

Essential

1. Expand observational nurseries for rainfed and irrigated environments.
2. Develop observational nurseries for tidal wetlands and adverse soils situations.
3. Perform "hot spot" screening for major biological stresses, to identify a wide range of genetic sources for host plant resistance and to study genetic variation in resistance to insects and diseases.
4. Organize nurseries with regional focuses to intensify efforts in Africa and Latin America, in cooperation with IITA, WARDA, and CIAT.
5. Characterize rainfed and adverse soils testing sites to better interpret varietal performance on the basis of more clearly defined target environments.
6. Intensify multilocation data analysis.
7. Rapidly disseminate diversified nursery reports tailored to location-specific needs.
8. Study genotype x environment interactions.

Desirable

1. Continue yield nurseries for various cultural types.
2. Start an observational nursery for exchanging japonica germplasm among interested national programs.

114 Integrated GIP

Varietal improvement activities will focus on developing improved germplasm for the five rice-growing environments. Research priorities for each environment are discussed below.

Irrigated rice

Rationale. Major advances in developing improved varieties for irrigated conditions have occurred during the past 20 years. More than 150 improved varieties selected from IRRI-bred materials and more than 500 improved varieties developed by national rice improvement programs are now planted on most of the world's irrigated lands. Rice improvement for irrigated conditions occurred progressively, in several stages:

1. development of high yielding plant type with short stature, lodging resistance, and high response to nitrogen, as exemplified by IR8;
2. development of high yielding varieties with superior grain appearance, such as IR20 and IR22;
3. incorporation of multiple resistance to disease and insects, as in IR26;
4. reduction in growth duration, as typified by IR36;
5. incorporation of tolerance to soil problems, as in IR42; and
6. incorporation of superior cooking and eating quality characteristics, as in IR64.

After the initial breakthrough in increasing yield potential, major attention was shifted to incorporating other desirable traits into improved varieties (such as yield stability and grain quality). Less attention was paid to further increasing yield potential, although per day productivity has been considerably improved by developing improved varieties with shorter growth durations. IRRI experience confirms that stable resistance to diseases and insects is difficult to achieve. Because breeders must continue to incorporate new genes for resistance into improved varieties to maintain yield stability, maintaining yield gains will remain an important component of IRRI's rice improvement program.

Advances in rice improvement to date have occurred through conventional breeding. IRRI will supplement these approaches with emerging biotechnology techniques, for further gains in yield potential. Similarly, IRRI will resort to genetic engineering techniques to move genes for disease and insect resistance and stress tolerance across sexual barriers.

Progress in improving irrigated rice has a direct bearing on improving rice for other environments. For example, if a useful gene for disease and insect resistance from a wild species is transferred to irrigated rice through conventional or genetic engineering techniques, it immediately becomes available for rice breeding programs focusing on other environments. Because more than 70% of the world's rice is produced from favorable environments, and because production under those environments is more vulnerable to changes in the races and biotypes of pathogens and pests, research on irrigated rice will continue. In addition to an adequate maintenance research program, innovative techniques will be used to achieve higher yield potentials and more stable forms of resistance.

Objectives

Essential

1. Incorporate diverse genes for disease and insect resistance to maintain yield stability and explore the possibility of incorporating durable resistance.
2. Improve yield potential through heterosis breeding and physiological research leading to higher biomass production.
3. Improve grain quality through incorporating pleasant aroma into the grain and through increased milling recovery.
4. Develop even shorter-duration varieties suitable for year-round rice-based cropping sequences.
5. Improve lodging resistance, particularly of short duration varieties.
6. Incorporate reasonable levels of tolerance to soil problems for increased yield stability.
7. Incorporate low-temperature tolerance into varieties for high elevation areas and temperate environments.
8. Incorporate high-temperature tolerance into varieties for high temperature, arid zones.

Rainfed lowland rice

Rationale. Varietal improvement activities will focus on rainfed lowland environments where drought, submergence, and stagnant flooding are the dominant constraints. Varietal characteristics that are important in raising the productivity of rainfed

lowland varieties are:

1. vigorous plant type with intermediate height;
2. drought tolerance;
3. submergence tolerance;
4. tolerance to adverse soils, such as those with P and Zn deficiency;
5. resistance to major diseases and insects, such as bacterial blight, blast, tungro, brown planthopper, gall midge, and stem borer;
6. good grain quality, and
7. appropriate growth duration to fit different rainfall and cropping patterns (photoperiod sensitivity is essential in some environments).

Objectives. Varietal improvement efforts will be directed toward incorporating traits that confer adaptation to rainfed environments. Because appropriate selection pressures do not exist at Los Baños, collaborative arrangements for evaluating segregating materials will be established with scientists in Thailand, Bangladesh, and India.

Essential

1. Develop photoperiod sensitive rices with improved plant type and other desirable characteristics.
2. Develop improved rices with moderate to high levels of drought and submergence tolerance (by themselves or combined).
3. Study yield stability and adaptation to unfavorable rainfed lowland conditions through farmers' fields and observation trials in the Philippines and elsewhere.
4. Study the interaction between genotype and agronomic practices in unfavorable rainfed lowland conditions.

Desirable

1. Develop improved, very late maturing, photoperiod sensitive rices for the rainfed lowland areas.
2. Develop improved rices with the grain quality and adaptability of Mahsuri variety, to increase the incomes of rainfed rice farmers.
3. Develop very short duration (100-115 day) photoperiod-insensitive rices with strong drought tolerance and improved plant type for transplanted or direct-seeded, drought-prone, rainfed lowland areas.
4. Develop improved rainfed lowland rices with resistance to gall midge.

Upland rice

Rationale. Rice yields in upland environments are low, and are frequently constrained by low soil fertility, drought, adverse soils, weeds, diseases, and insect pests. Most traditional cultivars possess tolerance to difficult soil and climatic stresses, but their low nitrogen-responsive plant type and susceptibility to lodging and pests severely reduce their productivity. The goal in upland breeding is to rectify the defects of traditional cultivars while retaining their desirable traits, such as popular grain quality and adaptability to adverse environments and low inputs.

The varietal characteristics important in raising the productivity of upland varieties are:

1. vigorous plant type, particularly during early stages, with intermediate height and competitiveness with weeds;
2. drought tolerance;
3. tolerance to adverse soils, such as those with phosphorus deficiency and aluminum toxicity, and high response to low-moderate cash inputs;
4. resistance to major diseases and pests, such as blast, brown spot, and stem borer; and
5. popular grain quality and appropriate growth duration to fit different rainfall and cropping patterns.

Objectives. Varietal improvement activities will be carried out in collaboration with national programs, since appropriate selection pressures do not exist in Los Baños. In addition to continuing to develop alternative sites in the Philippines (Caliraya, Claveria), collaborative arrangements for evaluating segregating materials have been established with Indonesia (SARIF, Sumatra), Brazil (CNPAF, Goiania), and West Africa (IRAT and WARDA, Ivory Coast).

Essential

1. Develop improved germplasm using diverse parents, including both tropical and temperate climate upland japonicas, that are adapted to low pH and low fertility. Some indica and aus varieties will also be used in combination with japonicas; these three groups are frequently complementary for some important traits.
2. Incorporate durable resistance to blast, a major constraint under upland environments.
3. Develop materials tolerant to phosphorus deficiency.
4. Improve screening methods, especially for drought tolerance, to identify potential parents for future crosses.

Desirable

1. Develop materials with seedling vigor for better stand establishment and weed competition.
2. Improve grain quality by incorporating intermediate amylose content and mild aroma.

Deep water rice

Rationale. The emphasis in the deep water rice breeding program will continue to be on developing improved germplasm for areas where water depth ranges from 50 to 100 cm, which includes most deep water areas. Improved materials for 50-100 cm water depth must have submergence tolerance, moderate elongation ability, medium stature, and photoperiod sensitivity. Cultivars for water depths in excess of 100 cm must have strong elongation ability. Prototypes having modern plant type combined with elongation ability and submergence tolerance have been developed for evaluation in areas subjected to sudden floods followed by deep water.

Objectives. Since there are no deep water areas in the Philippines, varietal improvement activities will be carried out in collaboration with national programs. Ongoing collaboration with Thailand, Bangladesh, India, and Vietnam will be strengthened.

Essential

1. Develop short-statured materials with photoperiod sensitivity, moderate elongation ability, and submergence tolerance for areas with water depths of 50-100 cm.
2. Develop photoperiod sensitive materials with strong elongation ability for areas with water depths of 100-200 cm.
3. Develop techniques for efficient, low-input, mass selection in farmers' fields.
4. Evaluate yield potential of advanced deep water lines in multilocation trials.

Desirable

1. Incorporate tolerance to low pH in improved deep water varieties for deep water areas with acid sulphate soils.
2. Develop photoperiod-sensitive varieties with strong elongation ability for areas with water depth of more than 200 cm.

Tidal wetland and problem soil rice

Rationale. Explicit attention to tidal wetlands as a unique environment with constraints different from other cultural types is a recent development in varietal improvement. The breeding work for this environment is at an early stage.

Several soil and climatic stresses either depress yields or prevent the cultivation of rice. Important soil stresses are salinity and alkalinity and mineral toxicities and deficiencies associated with acid, acid sulfate, and peat soils. Submergence, deep water, and drought are common climatic stresses. At present, losses caused by pests and diseases are not large, possibly because of the low yield potential of currently cultivated varieties. Increasing the yield potential and stability of traditional cultivars while retaining or further improving their adaptability and grain quality will be the first step in developing better varieties for tidal wetlands, as well as for soils characterized by toxicities and deficiencies.

The main constraints are limited germplasm, slow generation advance, undesirable linkages, difficulties in screening segregating populations under actual stress environments, and lack of donors for a high level of tolerance to certain soil stresses. Tidal wetlands, apart from soil and climatic stresses, have location-specific problems. To overcome some of these constraints, IRRI will develop collaborative research with India, Indonesia, Philippines, Thailand, and Vietnam. Shuttling early generation materials between IRRI and these national programs will permit exposure to appropriate stresses.

Objectives

Essential

1. Develop a collaborative research network wherein selected NARS and IRRI will jointly implement breeding programs for the major tidal wetland and problem soil types, accepting responsibilities where each has a comparative advantage.
2. Identify donors for various stresses and generate breeding materials.
3. Develop intermating populations to break undesirable genetic linkages in traditional cultivars.
4. Use innovative techniques, such as rapid generation advance, anther culture, and shuttle breeding, to expedite the generation advance of breeding materials.
5. Coordinate with the wide hybridization program to transfer adverse soils-tolerant traits of wild species to breeding populations.

Desirable

Improve the disease and insect resistance of varieties for tidal wetlands and problem soils.

IV. PA 200: Crop and Resource Management

IRRI's aim in crop and resource management research is to develop methods by which soil, nutrient, water, and climate resources can be used to produce rice and other crops grown in rotation with rice more efficiently, while maintaining or improving the resource base. More specific objectives toward achieving this broad aim relate to the efficient management of soil, nutrient, and water resources on a sustainable basis; the improvement of crop and pest management; and the development of farm machinery and postharvest activities. Together, these will lead to full and more efficient resource use that will generate income and increase employment opportunities.

Crop, soil, nutrient, and water management practices must be tailored to suit rice cultural environments. Research on management practices for each of the major rice environments must be conducted at appropriate research sites and evaluated on farms at representative sites — representative not only of the physical environment, but also of different socioeconomic environments. To promote this research effort, interdisciplinary task forces will integrate with the Germplasm Improvement (PA 100) and the Socioeconomic and Environmental Impact (PA 300) Programs.

Each of the five environments will require a research development site, one or more research refinement sites, and several on-farm locations where technology may be evaluated.

To meet the needs of rainfed environments, IRRI has consolidated its rice and resource management research programs and given them a stronger environmental focus. Subprogram Areas 201 to 206 are interdisciplinary, bringing together physical, biological, and social scientists concerned with the major factors affecting rice productivity and resource management for increased, sustained production. These programs will be concerned with the management of resources in each of the five major rice production environments. Some give greater emphasis to a particular environment; some are essentially environment neutral (e.g., pests that are of equal importance in several environments).

RESEARCH PRIORITIES FOR ENVIRONMENTS

Irrigated system

The major thrusts of future work in irrigated areas will be to sustain yields and increase input efficiency — specifically, use of fertilizers, pesticides, water, bio-fertilizers, and botanical pesticides — and to increase employment opportunities within the total farming system.

Because many national programs now have considerable experience and expertise in developing management practices to increase economic efficiency in irrigated rice, IRRI can reduce some of its efforts in this area. However, because relatively few national programs are willing to devote resources to long-term experiments to determine the sustainability of high yields, IRRI will continue to do some work in that area. Basic research focused on identifying processes to increase the efficiency of soil and resource management in irrigated rice production also will be expanded.

Rainfed lowland system

Within rainfed lowland rice regions, IRRI will give immediate priority to work on drought-prone, medium-deep, and waterlogged areas, although it is recognized that many technologies are not specific to these individual environments.

Research that will have high priority in the drought-prone areas include crop establishment methods, weed control, water conservation, nutrient (particularly nitrogen) supply, crop management in relation to water use, and crop intensification through prerice and postrice crop enterprises. In the medium-deep and waterlogged areas, research will include nutrient management, drainage and soil improvement, and crop intensification.

Upland system

Priority will be given to increasing the productivity of labor and power and to sustained and increased resources to improve land management systems. Blast is much more common in upland rice than in lowland rice, and is particularly important in

many parts of Africa. Weeds are also a major problem in upland rice. Management strategies to minimize the effects of blast, weeds, and nutrient (particularly phosphorus) deficiencies will be given priority. Upland rice interactions with other crops, particularly legumes, also will receive special attention.

Deep water rice

Methods of crop establishment and the possibility of modifying planting time by using varieties with different characteristics to increase cropping intensity will be studied where flooding patterns allow. Where these may be associated with development schemes to alleviate flooding problems, fertilizer use and methods of nutrient supply to realize the yield potential of the new deep water varieties will be studied. Integrated pest management (IPM) procedures will be developed that are compatible with the rice-aquaculture production systems common in deep water areas.

Tidal wetlands and adverse soils

Research will seek to determine the major crop production factors limiting rice yields on tidal wetland and adverse soils. Research at IRRI will focus on tidal wetlands, research on other adverse soils will be conducted through collaboration with national programs in target areas outside the Philippines. To complement tolerance of adverse soils in MVs, adequate ameliorations and amendments will be developed, including specific fertilizer and crop management practices.

RESEARCH PRIORITIES FOR SUBPROGRAMS

Priorities in research on crop and resource management are aimed at ensuring that the gains made in rice production technology are sustained, and that production of rice continues to expand in line with increased demand. Most activities will be concerned with technology generation for the environments where opportunity for progress exists, or where equity considerations demand that attention be given. We will slightly expand the small amount of attention we give to environmental characterization, as part of the rice-based farming systems subprogram (PA206), and integrate our management studies into on-farm trials at sites representative of different environments. We will support the on-farm studies with simulation modeling of cropping systems, their management and their economics.

To increase income from small rice farms, we will work with NARS and bilateral and international organizations through the Asian Rice Farming Systems Network to bring together the best available crop varieties and management practices for evaluation within a rice-based cropping system. To ensure that these technologies will be properly developed and evaluated, we will continue to improve our farming systems methodology, taking into account the importance of gender issues and of such income-increasing enterprises as rice-fish and rice-livestock sequences.

The rationale, objectives, and strategies to be followed are described for the following subprograms:

201 Soil and nutrient management
202 Water management
203 Crop management
204 Pest management
205 Farm machinery and postharvest management
206 Rice-based farming systems

201 Soil and nutrient management

Rationale. In IRRI's early years, research focused on nitrogen availability, management of certain problem soils, and the rather special conditions associated with alternatively oxidizing and reducing soil conditions. With the increased attention being given to rainfed and partially irrigated conditions, the influence of soil variables on crop production becomes more important, requiring greater efforts to ensure optimum use of soil and nutrient resources, rainwater, and solar radiation. The problems of soil fertility deterioration, erosion, and degradation under more intensive use require consideration, as does better use of adverse soils. Research on soil and nutrient management will focus on identifying and understanding processes causing productivity changes and on developing technologies for specific target environments.

Objectives

1. Establish which soils allow sustained high yields from rice and rice-based cropping systems and where soil productivity is likely to deteriorate if intensively cropped. Where needed, develop alternative methods of soil use to reverse soil deterioration while maintaining productivity.
2. Develop and evaluate in representative rice soils energy- and water-efficient techniques

of land preparation for flooded rice, using draft animal, machinery, and implements appropriate to resource-poor farmers.

3. Develop low-input methods of seedzone preparation and rootzone tillage in puddled and nonpuddled soils that allow rapid establishment and high production of nonrice crops grown before and after rice.
4. Establish the dynamics of organic matter in soils used for rice production and the ways in which organic amendments, including green manure, can be economically used to improve crop production.
5. Find ways to harness soil organisms, particularly nitrogen-fixing ones, to make an economic contribution to rice-based cropping systems.
6. Develop alternative strategies to minimize nitrogen fertilizer losses and maximize nitrogen use efficiency for irrigated, rainfed lowland, and upland rice.
7. Describe the kinetics, transformations, and interactions of essential nutrients in rice and crops grown in rice-based cropping systems to apply to developing appropriate management practices that will sustain high yields in different rice environments.
8. Find better ways to utilize and ameliorate adverse soils for rice crop production.
9. Evaluate advances in soil and nutrient management to help identify policies necessary to ensure their applicability in specific biotechnical and economic conditions.
10. Share advances in soil and nutrient management knowledge through the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER).

Strategies

1. *Soil fertility trends and management.* Continue or establish long-term experiments for rainfed lowland and upland rice and for rice-based cropping sequences in representative soil/climate environments. Study fertility changes and the soil, nutrient, and management factors that cause them. Factors needing study include fertilizer and pesticide management, organic manures, tillage and water regime, and nutrient balances. The processes of soil degradation, both physical and chemical, will be assessed in different soil types.
2. *Tillage and soil structure for rice.* For irrigated and rainfed lowland rice soils, determine the energy and water inputs required for various animal- and machine-powered land preparation methods and the effects of land preparation on soil structure and strength in the puddled and pan layers and on weed competition and rice rooting, growth, and yield; establish guidelines for rice-soil tillage and for development of improved implements; improve methods of measuring soil structure and strength and soil-water properties; apply existing geostatistical techniques for soil variability to permit standardization of soil-physical measurements.
3. *Seedzone and rootzone amelioration for nonrice crops.* For puddled soils, develop and evaluate appropriate technology and minimal-input, short turnaround methods for creating seedzone and rootzone structures favorable to nonrice crops; determine, using field and growth-chamber studies, the inter-actions of soil-water and temperature with soil mechanical and physicochemical factors (such as low oxygen concentration and chemically reduced status) on the germination and emergence of upland crops from seedzone structures. For nonpuddled soils, develop and evaluate low-energy methods for preparing seedzone structures for nonrice crops following upland rice.
4. *Dynamics and benefits of soil organic matter.* For tropical flooded soils, determine the chemical, physical, microbiological, and agronomic factors and practices controlling the accumulation, decomposition, mineralization, remineralization, and persistence of organic matter of various compositions; determine the effects of organic materials on soil fertility, nitrogen release, immobilization and fixation, other nutrient and toxin kinetics, soil/floodwater biomass production, and crop yields; develop practical methods for improving the fertility benefits of organic matter.

   Study the processes of nitrogen fixation by green manures (including azolla, blue-green algae, and sesbania) and the

associated nitrogen balances; develop methods for rhizobium inoculation in green manure species; evaluate short-term and long-term crop responses to cost-saving management practices that use combinations of inorganic fertilizers, crop residues, and farm-grown green and organic manures; determine (using ^{15}N techniques where appropriate) how fertilizer management affects nitrogen transformations, remineralization and immobilization, and residues of organic nitrogen. Ongoing, long-term field experiments for irrigated and rainfed lowland rice-based cropping systems have been started.

5. *Biology of flooded rice soils and nitrogen fixation.* Conserve, classify, improve, and make available a germplasm bank of biofertilizers azolla, blue-green algae, rhizobia, bacteria, and green manure species. Determine and quantify a) the dynamics of the microbial communities and the photosynthetic biomass in flooded rice soils (taking into account interactions with the whole soil ecosystem) so that the communities and the management factors influencing them may be manipulated to help control soil-nutrient and organic matter cycles, biological nitrogen fixation, and immobilization; and b) the effects of the transformations in microorganisms on nitrogen fixation, nutrient cycling, antagonism towards pathogens, growth-hormone production, and oxidation-reduction processes.
6. *Nitrogen transformation processes and nitrogen use efficiency in rice production.* Substantial progress has been made in understanding nitrogen loss processes in irrigated rice. This research will be gradually reduced, while research on loss mechanisms for rainfed lowland and upland rice will be increased. Compared with upland crops, nitrogen use efficiency in lowland rice is poor, seldom exceeding 30-40% at the farm level. Among the nitrogen loss mechanisms in lowland rice, ammonia volatilization and factors governing it have been shown to be of major importance. Recent research suggests that minimizing ammonia loss alone may not eliminate nitrogen loss from soil-floodwater systems. Other loss mechanisms, such as denitrification in the presence or absence of ammonia loss, appear to be operative.

   Management practices to minimize nitrogen losses and maximize nitrogen use efficiency will be evaluated for economy and farmer acceptability. Nitrogen management in rice-based cropping systems, particularly where legumes are included, will be a major focus for both irrigated and nonirrigated rice.
7. *Role of macro- and micronutrients other than nitrogen in rice-based cropping systems.* The available amounts of essential nutrients in soils may decline and become imbalanced as cropping intensity increases and following several years of high yields (particularly in low base soils), making it difficult to maintain high yields. Long-term fertility experiments indicate that continuous application of nitrogen alone may result in deficiencies of other nutrients, such as phosphorus, potassium, and sulfur. The deficiencies are especially enhanced when fertilizers and irrigation water do not contain adequate potassium or sulfur to meet the needs of the rice crop. Interaction between zinc and phosphorus also has been shown to be important. The dynamics of these nutrients in lowland and upland conditions must be understood to exploit fully the progress made in other areas of crop production. Studies will be made of nutrient availability in rice-based cropping systems in a range of physical environments and in systems utilizing organic and inorganic manures.
8. *Utilization and amelioration of adverse soils.* Continued pressure on land resources may necessitate further development of saline, sodic, acid sulfate, and peat soils.

   According to recent surveys, adverse soils occupy about 58 million ha in South and Southeast Asia, of which about 23 million ha could be used for rice production. Because adverse soils-tolerant rices are a prerequisite to successful cultivation in these soils, existing links with Subprogram Area 108 will be strengthened.

   Field research in the Philippines will focus on coastal saline (tidal swamp) soils, since saline soils are the most widespread of the adverse soils in the Philippines, with a

variety of representative sites. Research on alkaline, acid sulfate, and peat soils will be consolidated through collaboration with national institutions in respective target areas.

An adequate characterization of soil properties particularly those related to water regime and nutrient supply is basic to properly understand how to manage adverse soils for rice and to identify important plant characteristics. Adequate cropping patterns will be developed to achieve sustainable production levels on adverse soils.

Because the influence of soil variables on crop production is pronounced with adverse soils, a common code of site description, soil classification, and methods of analysis will be developed so that experience and technology can be transferred to comparable sites.

9. *Evaluation of nutrient management.* Evaluate the economic viability of innovations in integrated nutrient management. Identify under which market and institutional policies an innovation may be relevant and identify policies that would further increase the applicability of an innovation among small farmers in target environments.
10. *INSFFER.* Share research results in soil and nutrient management among scientists in national research programs through INSFFER. Currently, INSFFER includes 20 countries, mostly in Asia. The earlier focus on increasing fertilizer efficiency will be continued, but greater emphasis will be given to the use of organic manures (including green manures) in integrated nutrient management systems and to the long-term effects of intensified production on soil fertility in rice and rice-based cropping systems. These studies on sustainability will include attention to physical as well as chemical properties of soil degradation. Economic considerations related to INSFFER trial results will be used to discern economic, management, and policy implications.

Increased emphasis will be given to site characterization, to improve transferability of results. The Fertility Capability Classification (FCC) will be modified to suit the characterization of rainfed lowland rice sites. Studies of soil chemical properties will be complemented by studies of soil physical properties and hydrology, particularly in nonirrigated environments. A methodology will be developed to summarize and interpret soil, land, water, and climate parameters.

Basic research will be carried out with selected soil scientists to study nitrogen transformation processes in relation to management practices. Each collaborating scientist will decide on a research priority; INSFFER will provide the forum to discuss methodology issues and share results.

The activities of INSFFER will be linked with those of the ARFSN and IRTP and linkages will be established with other international soil management networks, such as the International Board for Soil Research and Management (IBSRAM) and the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT).

In all of the research thrusts under the Soil and Nutrient Management Subprogram Area, additional core resources will be needed to conduct relevant research in target environments outside the Philippines.

202 Water management

Rationale. Water is the most critical factor in increasing the production of rice and other crops grown in ricefields. A scarce resource in most environments, water must be conserved and used effectively, particularly in rainfed environments, to achieve higher productivity. In irrigated environments, it must be utilized efficiently to benefit as large an area as possible. While the emphasis of IRRI's research should be on the farm level, critical interactions of farm-level water status with local hydrology and with irrigation system management must be recognized, and problems identified must be resolved in collaboration with concerned agencies, such as the International Irrigation Management Institute (IIMI).

Large areas have suffered productivity losses due to irrigation-induced waterlogging and salinization. The long-term sustainability of irrigated crop production systems is questionable in those areas. In vast rainfed rice areas, waterlogging limits the rice growing season and occasional flooding

introduces high risks. Millions of hectares of riceland are either idle or marginally productive due to problems arising from salinity, alkalinity, and acidity; those can be ameliorated through appropriate water management.

In the past, water management research focused on increasing the efficiency of water use and distribution within the context of irrigation systems. The need for greater attention to the problems of rainfed production systems and on-farm technology generation is well-recognized, and is integrated into the current program. Future research will emphasize widely applicable water-related factors that are expected to become more critical for increasing crop production and the income of farmers, as well as for sustaining current production levels. Complementarity to the research undertaken by NARS and existing international agencies is a major consideration in the development of IRRI's research in water management. One area in which support may be obtained from appropriate institutions is in applying remote sensing techniques to the analysis and management of water in rainfed and irrigated environments. Recognizing the possible association of vector-borne diseases with flooded rice, IRRI will collaborate with the World Health Organization and other appropriate international and national agencies in monitoring that situation.

Objectives

1. Develop water management systems to increase the output of rice and other crops grown in rice-based cropping systems per unit of water supplied at the farm level.
2. Make effective use of water stored in the soil matrix and of groundwater.
3. Investigate economical methods of water collection and utilization for rice production.
4. Identify technically feasible and economical ways of alleviating drainage and waterlogging problems in rice producing areas.
5. Assess the temporal dynamics and economical advantages of allocating limited water supplies between rice and other crops.

Strategies

1. *Increasing farm water use efficiency.* Evaluate alternative techniques of farm level irrigation of rice and upland crops grown after rice to conserve irrigation water, including water used in land preparation, and to establish the relationships to management of other inputs, such as fertilizer, and to weed control. Assess the management and socioeconomic implications of new technologies and identify practical means for their adoption at the irrigation system level to increase command areas (In this area, considerable scope exists to collaborate with national and international agencies such as IIMI). To make rainfed systems less drought-prone, establish guidelines to lessen water use in land preparation. Study percolation and seepage for various soil types and hydrological regimes.
2. *Improving use of residual water for upland crops after rice.* For irrigated and rainfed lowland rice soils, determine the availability of water in unsaturated and saturated soil to crops grown after rice and develop methods of land preparation to make effective use of this water.
3. *On-farm rainwater storage.* Determine the technical and economic feasibility of alternative techniques of collecting, conserving, and using rainwater on the farm to stabilize wet season rice yields, to provide supplemental irrigation, and to produce dry season crops. Determine the suitability of rainwater collection techniques for diverse landscape and soil characteristics and develop optimal cropping technologies compatible with the resource base. Identify constraints to the effective storage and efficient use of rainwater and develop cost-effective means to alleviate constraints.
4. *Runoff control to optimize rainfall benefits for upland rice.* Develop rainwater conservation techniques for upland rice areas, such as planting semi-permanent strips of vegetation along contours.
5. *Assessing drainage problems in rainfed environments.* Characterize excess water dynamics and their relationships to rice production in typical rainfed areas, using remote sensing techniques and supportive cadastral and topographic map analyses. Develop methodologies to assess using such strategies as cropping calendar modification, early maturing varieties to escape flooding damage, and submergence-tolerant varieties to increase rice production.

6. *Alleviating drainage problems in irrigated environments.* Develop methodologies for typical irrigated rice systems to identify and evaluate the causes of drainage problems, assess crop production losses attributable to these problems, and evaluate alternative strategies.
7. *Drainage and rice productivity.* Determine the relationships of subsurface soil profile drainage rates to the maintenance of high land productivity in irrigated rice.

203 Crop management

Rationale. In rainfed areas, drought is often the most serious production constraint to establishment, growth, and yield of both rice and upland crops. Cultural practices that avoid or minimize drought damage are needed.

New rice crop cultural practices also are needed to overcome such constraints as high labor costs for transplanting and weeding and problems of flooding and crop lodging. For instance, where labor is unavailable or too expensive to permit timely transplanting of rice, direct seeding may be an alternative. The cultural practices associated with direct seeding merit further attention, not only for areas where labor costs continue to rise, but also to permit earlier crop establishment, helping the crop to escape drought or floods and allowing increased cropping intensification.

Ratooning or transplanting older seedlings than normally recommended also may permit increased cropping intensity and productivity. Any increase in rice cropping intensity offers an important opportunity to increase production and employment.

Deep water, upland, and drought-prone rainfed lowland rices, which have among the lowest yields, suffer a unique combination of stresses. New cultural practices potentially offer means of overcoming or avoiding the stresses associated with these environments and of assisting many of the poorest rice farmers.

Inclusion of upland crops (including green manure crops) either before or after a rice crop in various rice environments can allow cropping diversification and intensification. Improved crop sequences, intercrops, and relay cropping patterns adapted to different rice-growing environments will be developed. Component technology and management practices to ensure good, early stand establishment and efficient use of purchased inputs are needed for upland crops in rice-based cropping systems. Technology will be developed for productive and profitable rice-based cropping systems in relation to rainfall, solar radiation, soil properties, hydrology, and crop rooting system.

Currently, information is lacking on rice crop canopy photosynthetic efficiency in relation to stand establishment techniques and to cultural practices such as water, nutrient, and weed management. This area should be explored.

Rice genotypes that are excellent except for a single trait, such as lodging or stress susceptibility, may be produced or identified. The use of plant growth regulators with these genotypes may increase productivity until more suitable genotypes are found. Exploratory work is needed on the potential of growth regulators and mechanisms of stress tolerance.

Objective. Optimize productivity and profitability of rice and rice-based cropping systems in diverse crop environments through investigation of new crop cultural practices that improve yields and production, minimize input costs, and create employment opportunities.

Strategies

1. Identify the critical factors for determining the flow of water among soil, plant, and atmosphere to minimize water-stress damage in rice.
2. Develop cultural practices for broadcast and row seeding; evaluate seed treatments that may improve growth of direct-seeded rice; identify morphological and physiological effects of direct seeding on rice germination and growth.
3. Identify bottlenecks to rice productivity and develop economically viable cultural practices for irrigated and nonirrigated rice cultures.
4. To sustain increased productivity and profitability, intensify research efforts on growing upland crops, especially legumes, before and after rice in rice-based cropping systems and to develop alternative component technologies in relation to soil, water, and weather factors that effectively utilize moisture, nutrients, and crop residues. Evaluate rice ratooning for insertion of an additional rice or upland crop. Study green manure crops and their importance in nutrition, soil productivity, and market demand.

5. Assess rice crop growth and productivity by measuring canopy photosynthesis in order to improve establishment techniques and cultural practices for irrigated and nonirrigated environments.
6. To increase lodging resistance in MVs, investigate the effects of growth regulators on rice lodging. Use appropriate growth regulators to minimize other stresses, such as low temperature and drought.

204 Pest management

Rationale. Despite increases in rice yields brought about in recent years by improvement in the yield potential and pest resistance of MVs, pest-induced crop losses remain a major threat to the stability of food production. Losses due to insects, diseases, and weeds in individual countries or regions and in different rice environments range from 10% to more than 30%. The inherent capability of pest populations to adapt renders control using pesticides or resistant cultivars alone short-lived. Pest resurgence, emergence of new insect biotypes and pathogen races, new weed problems, and secondary pest outbreaks continue to haunt rice production, particularly in the humid tropics where rice is grown throughout the year.

Uniform crop cultivars are often grown over large areas, which greatly favors disease epidemics and insect outbreaks and perpetuates weed problems. Long term pest management relies on ecological methods of lowering the carrying capacity of rice ecosystems through a) planting different cultivars for dry and wet seasons, b) introducing within-stand cultivar diversity, and c) planting nonrice crops to break pest cycles.

A systems approach will be used to analyze pest problems, disease epidemics, insect outbreaks, and weed infestation in rice and rice-based cropping systems in different climates and with different cultural types. The program is based on concepts of IPM. Relevant components of pest management will be identified and studied to fit the cropping systems of specific environments.

Collaboration with scientists in national research systems, FAO, and other international organizations will be strengthened to involve them in problem identification and project development and to obtain feedback on the potentials of various technologies. To achieve this, an international pest management working group will be organized to deal with major pests prevalent in many countries.

Objectives

1. Achieve yield stability in the various rice environments with minimal inputs, using improved pest resistant rice cultivars as the major component.
2. Generate the necessary knowledge base for effective IPM practices that are acceptable to farmers.
3. Pay increased attention to the management of pests in rice-based cropping systems.

Strategies. To sustain rice production systems with regard to pest management, crop loss assessment will be initiated to establish economically effective monitoring and early warning systems, in collaboration with agencies such as FAO and NARS.

To quantify the effects of rice pests as constraints to rice yields, the subprogram will evaluate management strategies through the following activities:

1. Develop forecasting models and pest thresholds based on quantitative analysis of pest incidence and progression. Determine the relationship to pest abundance and yield loss.
2. Develop genetic and molecular tools for disease diagnosis, plus appropriate monitoring techniques.
3. Determine environmental factors and cultural practices that affect pest incidence in rice-based systems.
4. Use indigenous and exotic natural enemies for biological control of selected rice pests to reduce the need for chemical control by a) augmenting and conserving natural insect predators, parasites, entomopathogens, and plant pathogen antagonists; and b) utilizing microbial pesticides in IPM programs. Continue the program wherein cultural management of improved rice cultivars with high yield and pest resistance provides a basis for pest control that aims to
   a. enhance durability of pest-resistant cultivars by using improved cultivars as a means of pest management such as genetically diverse rice cultivars for different cropping seasons, within-stand diversity, and nonrice crops;
   b. promote cultural control for upland rice;
   c. develop integrated practices to control weeds in direct seeded rice;
   d. determine characters of rice cultivars that

impart competitiveness with weeds, particularly for rice seeded into dry soil;

e. evaluate hand-operated and animal-drawn cultivators for controlling weeds and study the feasibility of combining this operation with fertilizer or pesticide application; and

f. evaluate interactions between pest management and crop management.

Continue the chemical control program that aims to

a. evaluate insect growth regulators, repellants, attractants, and selected conventional pesticides for laboratory and field control trials;

b. evaluate plant derivatives for insect control to meet the needs of resource-poor farmers;

c. evaluate herbicides for different weed control programs in rice, with more focus on rice planted in dry soil and on weeds that build up as a result of weeds escaping herbicide treatment; suitable chemical combinations will be evaluated against difficult weeds, especially in harsh environments;

d. study the susceptibility of rice cultivars and weed ecotypes to herbicides; and

e. evaluate commercially available sprayers and devise inexpensive equipment to increase efficiency, reduce application rates, and reduce harmful environmental effects.

5. Determine the compatibility of various components of pest control through:

a. experiments on IPM, involving farmers to identify problems and research priorities in the field; evaluate experimental performance and compared it with the practices being used by farmers; feedback from farm communities will identify deficiencies in either basic or management components of disciplinary and interdisciplinary research; and

b. intensified research on integrated practices to control perennial weeds.

205 Farm machinery and postharvest management

Rationale. Increasing the productivity and profitability of rice-based farming systems is one of IRRI's goals. In double cropped areas, farm mechanization is needed to reduce turnaround time for increasing cropping intensities. With increasing costs of farming inputs (fuels, fertilizers, pesticides, etc.) farm mechanization is becoming an important factor in improving farmer productivity. Similarly, postharvest research directed toward reducing losses, conserving grain quality, and utilizing surplus biomass can help augment farmer incomes.

Reducing farm drudgery through appropriate mechanization can help improve the quality of rural life and retain young people on the farm. Small-scale mechanization in tropical Asia will permit greater involvement of women in rice farming, as has been amply demonstrated in Japan, Korea, and Taiwan. Farm machines specially designed for low-volume production permit local manufacture with low capital investment. Manufacture of simple farm machines by rural-based shops helps to generate employment and absorb surplus farm labor.

In the past, farm machinery development at IRRI concentrated on machines for irrigated lowland rice farming. While some attention will continue to be directed to solving mechanization problems in the irrigated areas, increased attention should be devoted to the needs of the less favorable rice environments. In postharvest research, collaborative work with national institutes and with regional and international institutes should be encouraged.

Objectives. The general objective of Subprogram Area 205 is to develop simple tools and equipment suitable for small landholdings to enable both men and women farmers to increase production and income. The specific objectives are as follows:

1. For the less favorable areas, such as rainfed lowland and upland, develop low-cost machines to enable farmers to prepare land quickly after the wet season for timely crop establishment, for proper crop care, and for supplemental irrigation to ensure survival of a second crop in the dry season. For poorly drained and waterlogged areas, where soils are soft and machine mobility is a problem, develop lightweight, low ground-pressure tillage and other equipment. Develop appropriate machines to effectively utilize land, labor, water, and other resources to increase production through increased cropping intensity.
2. Design machines to permit more efficient use of purchased inputs, such as fertilizers and pesticides, and equipment to effectively utilize farm-grown inputs, such as biofertilizers.
3. Reduce losses and conserve grain quality in

harvesting, threshing, and drying operations by directing research to improving harvesting and threshing equipment and developing appropriate grain drying systems for on-farm operations. Utilize surplus biomass (straw, hulls) as a fuel source for drying.

4. Identify practices that will reduce losses during harvesting, threshing, and milling.
5. Work closely with NARS in machinery testing, adaptation, and promotion of local manufacture of IRRI machines, to ensure that the machines are well suited to local agro-industrial conditions and are effectively utilized by a large number of rice farmers.

Strategies

Essential

1. To shorten turnaround time and increase cropping intensity, develop equipment for:
   a. land and seedbed preparation for rainfed lowland and upland conditions, including minimum and zero tillage devices;
   b. low ground-pressure tillage for soft and waterlogged soils;
   c. crop care (seeding, weeding, etc.) under rainfed lowland and upland conditions; and
   d. low-cost supplemental irrigation for rainfed lowland areas.
2. To reduce production costs and increase farm income, develop equipment for:
   a. increasing the efficiency of such farm inputs as organic and inorganic fertilizer, herbicides, fuels, and seeds; and
   b. energy-efficient tillage.
3. Reduce postharvest losses and conserve grain quality by:
   a. improving harvesting, threshing, and grain-cleaning equipment;
   b. developing low-cost multicrop dryers;
   c. devising low-cost methods and equipment for accelerated drying of rice; and
   d. conducting techno-socioeconomic studies to assess and improve the management techniques necessary to reduce postharvest losses and maintain grain quality.
4. Maintain closer coordination with scientists in other research areas to identify research priorities and equipment needs.
5. Promote local production of small-farm machinery by:
   a. testing, evaluating, and adapting IRRI-developed machines, in collaboration with NARS;
   b. providing technical assistance in the production of IRRI-developed machines; and
   c. assisting national research institutions in developing their own capabilities in designing commercial-style farm machinery.

Desirable

1. Develop techniques for gasification of rice hulls and crop residue to be used as fuel for internal combustion engines.
2. Devise machinery for home and industrial uses of rice hulls, straw, and other agricultural wastes, (e.g., rice hull carbonizing and briquetting).

206 Rice-based farming systems

Technological options that provide the bases for increased productivity and cropping intensity are generated through laboratory and experiment station research. These components must be integrated and adapted through on-farm research to develop more productive rice-based farming systems in the major rice environments. On-farm testing will provide feedback to the research process on the limitations of new technologies and insights into farm-level problems that require research attention.

IRRI must analyze the environments in which rice is produced to interpret the extent of problems and the areas over which technologies are appropriate. Systems modeling will contribute to this evaluation.

IRRI has played an active role in the development and popularization of cropping systems research methods in Asia. Procedures require refinement, particularly in identifying subsidiary or nonrice enterprises for income generation and in increasing farmer participation in the identification of research needs and the evaluation of technologies. Integration of technologies for female occupations as well as the participation of women in technology development and transfer will receive specific attention in IRRI's farming systems research.

This Subprogram Area is divided into the research concentrations discussed below.

Environmental analysis

Rationale. An international system for classifying rice-growing environments was recently proposed by IRRI (1984). This classification resulted from the increasing awareness of the difficulty of transferring results between environments, because environmental determinants of technology adaptation were not sufficiently understood, and from the need to develop better varieties and management practices tailored to disadvantaged areas and underprivileged farmers. Efficient identification of research priorities, evaluation and extrapolation of results, and assessment of the consequences of technology are possible only when the target environment is precisely defined in terms of its physical, biological, and socioeconomic characteristics.

Objectives

Essential

1. Use environmental analysis to help define research priorities within and among rice environments.
2. Identify areas of impact for specific developments in rice and rice-based cropping systems technology.
3. Increase the efficiency of selecting research sites to represent desired sets of physical environmental conditions.
4. Assist in interpreting data drawn from the international research networks.
5. Develop procedures to analyze the spatial and temporal variability of rice environments.

Desirable

Combine crop simulation and farmer decision models to predict the performance and evaluate the likely farm-level impact of rice-based cropping systems environments.

Strategies. Establishing research priorities on the basis of more precise knowledge of the importance of various rice environments is critical in determining IRRI's future thrusts. Research focus will be to identify the areas of the various classes and subclasses of all rice environments.

Extrapolation domains for new rice technologies must be determined. Environmental characterization and analysis will assist the international research networks (IRTP, INSFFER, and ARFSN) in interpreting the rich multilocation data sets they assemble.

Methods to increase understanding of the spatial variability in rice environments will be investigated through the development and analysis of rice environmental data bases. Temporal variability in rice environments will be investigated through simulation modeling.

Technology integration

Rationale. IRRI's farming systems researchers will conduct on-farm research in association with national rice programs and with farming families in locations where major research issues are common to broad classes of similar environments, based on technologies developed by PA 100 and 200 and NARS. The on-farm research interface provides a means to sharpen the research focus, identify priority problems, and integrate technologies generated through research at IRRI and other organizations. Research in technology integration will focus on aspects of crop sequences and rotations, on specific rice environments and on those aspects of the IRRI research that deal with crop interactions and with water and pest management.

Objectives. The objectives of Technology Integration are to conduct on-farm research that will

1. Refine management practices that promote the establishment and productivity of crops within rice-based cropping systems.
2. Evaluate cultivars of rice and nonrice crops in rice-based sequences in relation to agronomic and economic management systems and physical, market, and institutional conditions.
3. Design and evaluate improved crop sequences, intercrops, and relay cropping patterns adapted to the physical and economic resource constraints in major rice environments.
4. Evaluate pest management strategies to improve and sustain the productivity of cropping systems in major rice environments.
5. Evaluate tools, machines, and crop management practices designed to break labor and power bottlenecks that impede the adoption or expansion of nonrice crops grown in sequence with rice.
6. Evaluate management systems that increase and sustain the productivity and sustainability of crop sequences. Integrate green manures into crop sequences, as appropriate.

7. Develop and evaluate technologies for increasing household income and employment opportunities, with emphasis on women.

Strategies. IRRI and cooperating scientists will characterize the technological and socioeconomic opportunities and limitations of major rice environments and integrate component technologies and crop sequences that will improve resource productivity and profitability. On-farm research in the Philippines and elsewhere will continue to support a cluster of NARS farming systems sites located in similar environments. These clusters of sites, with common physical environments and crop, soil, and water management problems, are in professional contact with each other through the ARFSN and IRTP. Simulation modeling offers the potential to assess the zone of extrapolation and the productivity and stability of technology developed through site-based research.

Additional sites representative of dominant rice environments must be selected as points of focus for on-farm research outside the Philippines. This will require increased allocation of IRRI scientist time and budget to operate sites in cooperation with national programs.

Methodology development

Rationale. Methodology for conducting rice-based cropping systems research has been developed. However, it still needs to be refined in terms of farmer participation, production stability and sustainability, economic analysis, and equity issues, as well as adapted to fit local environments and the specific needs and constraints of a particular national program. Furthermore, the methodology must be expanded to incorporate nonrice and noncrop components — an integral part of farming systems research.

Objectives

1. Refine the present cropping systems methodology in the following four aspects:
   a. farmer participation in identifying research needs and in evaluating technologies;
   b. socioeconomic analysis, including equity issues;
   c. production stability and sustainability of rice-based cropping systems;
   d. adaptation to fit national program needs.
   e. delineation of the recommendation/extrapolation domain of newly developed rice-based cropping systems; and
   f. microcomputer-based data management systems.
2. Develop a methodology to incorporate nonrice and noncrop enterprises into cropping systems methodology.

Strategies. The socioeconomic component of methodology development will focus on

a) farmer participation in problem identification, setting bounds on research options, and evaluation of research;
b) equity (including poverty and gender-related) issues in setting research priorities, in technology design and evaluation, and in impact assessment;
c) farm management analysis to increase the cost effectiveness, timeliness, and utility of economic analysis of component technology and cropping pattern trials;
d) more explicit recognition of market and institutional-related determinants of feasible technology options;
e) issues of group decisionmaking and cooperation in resource management/technology use (e.g., water management, IPM); and
f) farming systems research within a broader national policy perspective — product and input policy, import substitution, or export-oriented objectives.

Farm-focused research will be closely linked to PA 300.

Systems-based methods to evaluate technology leading to increased, sustainable production, particularly in rainfed and upland rice environments, are not well developed. We will help develop such methodologies, particularly for upland sites where appropriate land management is critically important, in collaboration with such agencies as IITA, EMBRAPA, and the Indonesian Agency for Agricultural Research and Development.

The present methodology calls for testing new technologies in many sites suspected to be part of the recommendation/extrapolation domain. Because this process is both time-consuming and expensive for most national programs, guidelines based on relationships between technology performance and environmental parameters need to be developed to adequately predict the coverage of all recommendation/extrapolation domains.

Data generated through rice-based cropping systems methodology, which are generally diverse and voluminous, need to be effectively managed.

Recognizing the constraints NARS face in the availability of human resources and computer hardware and software, the data management system to be developed will be microcomputer-based, user-friendly (i.e., not dependent upon highly qualified computer personnel), and decentralized (i.e., management on a regional basis rather than confined to a central office).

IRRI recognizes that such nonrice enterprises as other cereal crops, horticultural crops, fish, livestock, and the use of rice byproducts can exploit some agroecological and seasonal niches more profitably than rice, to offer opportunities to raise farm income, increase rural employment, and improve nutrition. IRRI also recognizes that, while it has expertise in rice-based cropping systems research, it does not possess a comparative advantage in farming systems research in a broader context. Therefore, IRRI will promote the use of alternative income-generating practices through the ARFSN and collaboration with national programs and other international and regional institutes with specific expertise in nonrice components of rice-based farming systems.

Women in rice farming systems

Rationale. Women play an important role in agriculture, as laborers, managers of farm-related activities, and participant decisionmakers in input use, labor allocation, technology adoption, and marketing. But historically, women have not been culturally perceived as farmers and farm laborers; the "reference farmer" has almost always been male. Consequently, the traditional target user-beneficiary of technology generation, agricultural information, extension, training, credit, organization, and policies has been male.

Consistent with the Institute's and CGIAR's goal of advancing the welfare of rice-farming communities and rice-dependent households through research and knowledge-sharing, the incorporation of women's issues into its research, training, and collaboration with national programs will not only contribute to the identification of a wider path to equity and welfare, but will also enhance the relevance and content of its substantive programs.

IRRI has been a leader among the IARCs in the incorporation of women's issues into the agricultural research process. The Institute has established a modest research program of its own on Women in Agriculture and collaborates in action research with national scientists in Bangladesh, India, Indonesia, Nepal, Philippines, and Thailand. This impetus must be maintained and consolidated.

Objectives

1. Develop and disseminate technology tailored to the needs of women engaged in rice-based agriculture.
2. Identify and promote mechanisms that increase sensitivity to women's needs and expertise in the agricultural research and extension processes.
3. Evaluate the extent to which these concerns promote women's interests and contribute to the positive effects of technical change on women's welfare and the welfare of rural households.

Strategies. The basic approach is to work with national programs in identifying technology that is adapted to the requirements of rice-farming women and opportunities that exist in major rice environments. This research, closely integrated with the ARFSN, will be particularly concerned with women and technology development, women and extension, and the impact of new technology on women and the household.

IRRI recognizes that this area of research is at an early stage. A major challenge is to develop methodologies and techniques that increase awareness and sensitivity to women's issues. Sensitization of agricultural scientists, policy makers, and extension workers will also be pursued through the ARFSN.

Complementary micro-level research on the dynamics of agricultural household behavior, rural labor markets, and the policy environment affecting farm and household decisions will be linked to the research of Livelihood Impact Assessment (PA 303).

Asian Rice Farming Systems Network (ARFSN)

Rationale. Through the ARFSN, scientists in Asia and IRRI jointly develop and evaluate rice-based farming systems methodologies and technologies and, through adaptive research and extension, apply this knowledge for the benefit of Asian rice farmers. Although the focus is Asia, the network collaborates with farming systems networks in Africa and Latin America.

Objectives

1. Provide mechanisms for sharing information, technology, and methodology generated by national programs, IRRI, and other international centers.
2. Establish collaborative research on farming systems, with the major emphasis on problems common to Asia.

3. Provide a feedback mechanism to call the attention of IRRI and national research systems to field-identified problems.

Strategies. The ARFSN will continue to work with national programs in each of the major rice environments. In particular, it will serve as a mechanism to share knowledge between national programs and IRRI and to identify research issues and their solutions. The ARFSN will continue to promote methodology development in rice-based farming systems research and will collaborate with national programs on major problems of increasing the productivity and profitability of rice-based farming systems. It proposes greater collaboration in research on farm machinery and implements for intensive cropping, Prosperity Through Rice, and other problems identified by the Asian Rice Farming Systems Working Group.

The ARFSN also will continue to foster linkages among national rice-farming systems programs, NARS, and regional and international programs in those areas of farming systems research where IRRI does not possess a comparative advantage. Lead institutes that collaborate with ARFSN in nonrice crops include the University of the Philippines at Los Baños (UPLB), the Indonesian Central Research Institute for Food Crops, and the Thailand Field Crops Research Institute; CGIAR-sponsored centers such as IITA, the International Potato Center (CIP), and the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), as well as the Asian Vegetable Research and Development Center (AVRDC). Livestock expertise is gained from UPLB and Winrock International, agro-forestry capability from the International Council for Research in Agroforestry (ICRAF), and fish culture from the International Center for Living Aquatic Resources Management (ICLARM).

V. PA 300: Socioeconomic and Environmental Impact

Since its inception, IRRI has been concerned with the impact of modern rice technology. This concern is manifest in IRRI's consequences research, which focuses on the aggregate supply and equity impacts of modern rice technology. Similarly, factors that have limited adoption, yields, and efficiency of modern rice technology were evaluated within the Institute's constraints program. Because of their strong interdependence, it is timely for IRRI to integrate these socioeconomic and production concerns with farm (micro) and aggregate (macro) perspectives, and to add a third dimension: evaluating the impact of new rice technology on both the local and global environment. In short, it is critical that IRRI be able to evaluate the broader impact of new rice technology and associated systems of land management, to ensure that the technology designed has desirable impacts on those it is supposed to benefit while not disadvantaging others and to guarantee that it is ecologically sustainable.

The fact that agricultural research is a means to improve the livelihood security and basic life support system of people that increasing yields is not an end in itself is specifically recognized in the recent goal statement of the CGIAR. CGIAR and IRRI accord highest priority to:

- increasing and sustaining the livelihood of poor, rice-dependent households;
- increasing and sustaining farm productivity and profits in adverse rice-growing environments;
- increasing employment opportunities by making fuller use of resources, ensuring an equitable impact of new rice technology, and, where necessary, suggesting remedial measures; and
- assessing the environmental impacts of current and emerging rice technologies and providing remedial measures to safeguard the environment.

The manner by which IRRI must evaluate its research and training programs, and the manner by which the technology with which the Institute is associated is evaluated by others, is changing. The Institute must adapt and develop procedures to facilitate this broader evaluation of its work, and of emerging rice technology, in relation to the above goals.

An allied reason for IRRI's increased concern for evaluating technology from welfare and environmental perspectives is the commitment to direct a greater research effort to disadvantaged rice environments. These environments tend to be more fragile and their populations poorer. Therefore, the impact of technical change on the livelihood security of people and on the environment (both at the site and downstream) may be more dramatic, and may require greater ecological balancing than was the case in irrigated and favorable lowland rice areas.

A third reason for IRRI to evaluate its research from an ecological perspective is the close interrelationship between the welfare of people and the level of environmental husbandry. Thus, IRRI's concern for the impact of rice technology on the environment relates directly to the level and sustainability of agriculture as it affects income, nutrition, health (pollution, vector-borne diseases), and other quality-of-life indicators. On the global scale, there are concerns about our fragile atmosphere, owing to the impact of climate warming (known as the "greenhouse effect") and the depletion of stratospheric ozone. What are the implications of rising CO_2 concentrations in the air and the levels of the oceans for future rice production? Conversely, the well-being of people (wealth, access to resources), socioeconomic pressures or incentives, institutions, and policies determine the manner in which people manage the environment. In turn, the status of the environment and the well-being of people will determine research priorities and the productivity of resulting rice technology. Clearly, IRRI must design and evaluate research alternatives with consideration for both socioeconomic and environmental impacts.

PA 300, Socioeconomic and Environmental Impact, is designed to provide IRRI with the capacity and focus for impact assessment.

Technological responses to the assessment will be developed in association with concerned national agencies and with components of PA 100 and 200. Additionally, PA 300 will research policy-related factors designed to enhance the desirable impact of current and emerging rice technology. At a later date, the Institute may also participate in research to study the interactions among people, rice technology, and the environment as they affect the well-being of people locally and globally. The substantive innovations for IRRI in this program area are the impacts on the environment, their interactions with features of agricultural pricing and policy, and the intrahousehold equity implications of proposed and emerging rice technology.

Objectives

1. Adapt and develop cost-effective methods of impact assessment, particularly for interactive impacts on socioeconomic and biophysical features.
2. Evaluate the impact of emerging and existing rice technology on production, income and employment, other livelihood indicators of target populations, and the stability and sustainability of resultant farming systems.
3. Conduct research in cooperation with other agencies with expertise in social and environmental monitoring, with national and international environmental protection agencies, and with national rice programs to evaluate in various environments the socioeconomic and ecological impacts of new rice technology and intensified rice-based cropping systems.
4. Advise IRRI and national programs of the likely socioeconomic and environmental consequences of technologies that may emerge, given different priorities and directions of rice research, and collaborate in research that responds to these consequences.

To achieve these objectives, PA 300 will have three interlinked components: evaluation of the impacts of new technology on people, on rice production, and on the environment. The final level of analysis is livelihood assessment, as IRRI is ultimately concerned with the welfare of people and society in general — farm households, landless laborers, urban consumers — as they may be positively or negatively affected by technical changes in the rice sector.

Subprogram area

301 Environmental Impact
302 Production Impact
303 Livelihood Impact

The proposed research program in impact assessment is modest. Initially, IRRI plans to allocate 3-4 core scientist years to this activity mostly to PA 302 and 303. Subsequently, additional resources (perhaps from special project funding) to the equivalent of 3-4 scientist years, plus logistic and technical support, will be required.

Strategies. In addition to being the primary focus of PA 300, impact analysis at IRRI is undertaken in PA 100 and 200. Within PA 100 and 200, impact analysis will deal primarily with micro (or direct) effects at the farm level, in both the ex ante and ex post sense, to provide immediate feedback to researchers of the ex ante impact throughout the research process. From a hierarchical viewpoint, the micro-level evaluation in PA 100 and 200 provides the building blocks for broader evaluation from the perspective of PA 300. Operationally, PA 300 will be closely linked to PA 500, so that new technology is evaluated within the socioeconomic and environmental milieu of rice-growing countries.

PA 300 will integrate micro and macro analyses, taking into consideration general equilibrium effects (i.e., direct and indirect effects), ex-ante-ex-post dimensions, and the relationship between impact (net benefit) and cost of developing alternative technologies. The latter allows impact analyses to have a more concrete input into recommendations for technology design and into the setting of priorities for rice research at IRRI and in national programs.

A macro perspective of impact analysis is essential to understanding the full implications of any new technology, as many of the more important pervasive effects cannot be observed and understood at a micro level. It is also essential to effective communication with national policymakers, as their concern is for national welfare, not simply for a given rice village or certain rice farmers. Policy analysis is also a key component of the broader assessment of proposed or emerging rice technology, as its effects depend not only on the nature of the new technology, but also on national policy and institutional frameworks. Furthermore, the socioeconomic or environmental effects of new technology may require policy changes to enhance

and sustain the benefits from technical change or to mitigate any adverse effects.

IRRI will collect and use secondary data to evaluate the socioeconomic and environmental impacts of emerging rice technologies and of rice-based farming systems. This will include constructing and maintaining data bases to facilitate broader assessment of technology by IRRI and other concerned agencies. IRRI recognizes that its own input to environmental impact analysis will be modest. It will actively seek to collaborate with national programs concerned primarily with the protection of the environment and with others with specific expertise, to permit an evaluation of processes that lead to desirable or undesirable impacts of technology on people and the environment.

Analysis of the desirable and undesirable effects of future rice technology on people, the human environment, and quality of life demands a level of analysis and an interdisciplinary cooperation that transcends disciplinary research boundaries. This program area will attempt to integrate the analysis of the impact of new and emerging rice technology and policies from a broad perspective, using the rice economy, region, or country as the unit of analysis.

301 Environmental impact. In the coming decades and centuries, the farmers of the world will have to produce more and more food from shrinking land resources. This is particularly the case in South and Southeast Asia, where already high population pressures on land necessitate a constant quest for higher yields per crop and more crops per year. Attention to the impact on ecological sustainability of high yield technologies assumes urgency in the context of highly intensive and exploitive agriculture. Subprogram Area 301 is designed to examine the impact of modern rice technology on the environment and to study issues relating to the long-term sustainability of high yields in rice farming areas, through research where IRRI has a comparative advantage.

A distinctive feature of PA 301 is its complementarity with PA 200. For example, environmental assessment will have a strong interaction with the Environmental Analysis component of Rice Based Farming Systems (PA 206) and with the Environmental Data Service (PA 606). Similarly, impacts of irrigation development will be closely tied to Water Management (PA 202); research in the areas of production stability and sustainability will be closely integrated with Soil and Nutrient Management (PA 201), Crop Management (PA 203), and Rice Based Farming Systems (PA 206).

IRRI's expertise in environmental impact analysis focuses at the level of rice field and rice farm. In consequence, our expertise is highly complementary to national institutions with responsibilities for environmental monitoring and protection. Thus, one distinctive feature of PA 301 will be collaboration with national agencies whose particular responsibility is in environmental monitoring. Another distinctive feature is the proposed collaboration with international agencies that have particular expertise in environmental management and monitoring (e.g., IBSRAM for soil management in fragile rice environments, UNEP and the United States Department of Energy in environmental impact, IIMI and the Panel of Experts on Environmental Management for Vector Control (PEEM) in water-related issues, and the Commonwealth Institute of Biological Control (CIBC) in pest management).

The areas of research in which IRRI has both expertise and on-going programs can best be examined in relation to the five major components of humankind's life support system – soil, water, flora, fauna, and the atmosphere. These are briefly discussed below.

Soil - An important mechanism for examining properties of soil health in relation to the sustainability of high yields is the INSFFER network, particularly through INSFFER's concern for conserving soil productivity. Chemical, physical, microbiological, and toposequence aspects of soil health care should receive integrated attention. Establishing the integrated nutrient supply systems that will help maintain soil fertility status involves studying optimum combinations of green manure, bio-fertilizers, organic manures, and mineral fertilizers, supported by management of soil-physical conditions, especially in fragile uplands. The economic benefit for farmers of environment-conserving procedures is also a concern. IRRI plans a series of symposia on sustainable agriculture; the first, in May 1987, will deal with the role of green manure crops in rice farming systems. IRRI is also restructuring INSFFER as a Soil Fertility and Sustainable Agriculture network.

Water - The work of IRRI's Water Management Department will include studying the role of irrigation water in causing such soil problems as

waterlogging, alkalinity, and salinity. In addition, the relationship of ricefield water management to the breeding and propagating of vectors of major human diseases will be studied. Potential contamination of groundwater caused by the percolation of residual fertilizers and pesticides into aquifers used for domestic water supplies will be assessed in representative rice growing areas. The role of rain and irrigation water in enhancing soil fertility, for example by increasing sulfur content, also will be studied. Most of these research activities will be in collaboration with appropriate agencies, institutes, and universities.

Flora - A common criticism of the introduction and intensive cropping of high-yielding varieties of rice and other cereals is that they displace a large number of traditional varieties and lead to monoculture and/or staggered plantings of the same genetic strain over millions of hectares. Genetic heterogeneity is lost and genetic homogeneity, is introduced, resulting in genetic vulnerability to pests and diseases. IRRI is adopting a 3-pronged strategy toward solving this problem. First, IRRI has pioneered the collection and conservation of a representative collection of wild and cultivated strains of rice. The International Rice Germplasm Center represents the world's most well-organized effort to conserve for posterity a full array of the genetic variability resulting from both natural evolution and natural and human selection. Second, a large pool of germplasm drawn from IRRI and NARS is distributed widely through IRTP, making it possible for NARS to breed varieties with specific adaptation to local conditions. This mechanism also makes it possible to identify, under each maturity category, several varieties with diverse genetic makeup, thereby promoting genetic diversity. Third, using genetic engineering and tissue culture techniques to overcome the problems arising from sexual barriers, IRRI is trying to introduce new genes from wild species into cultivars.

Fauna - IRRI's emphasis on conserving the fauna in rice farming areas has two aspects. First, conservation of the natural enemies of pests and pathogens is receiving high priority (the recent publication on "Friendly Insects" is an example). Second, controlling grazers so that the native soil micro-flora, including blue-green algae, can be protected is being studied. More emphasis is being placed on management of the total photosynthetic aquatic biomass (algae and aquatic plants).

Atmosphere - Atmospheric problems, such as higher CO_2 concentration, depletion of the ozone layer, and acid rain, can only be tackled by international collaboration to restrict the use of coal and fossil fuels, to prevent deforestation and promote afforestation, and to reduce chlorofluorocarbon (CFC) emissions. Control of greenhouse gas releases will be essential in maintaining the earth's climate as close as possible to that of the past several thousand years. IRRI conducts research on ammonia volatilization and denitrification in fields fertilized with urea, as well as the release of methane and other hydrocarbons from ricefields. Work on deep water rice may assume greater significance in the coming years, if inundation takes place due to a rise in sea level caused by ocean warming.

302 Production impact. Analysis of rice production and its components by country in the Asian region and globally will remain an important component of IRRI's research. Food security depends on production stability. Therefore, IRRI will continue to examine the impact of new rice technology on production, production stability and sustainability and to study how science, institutions, and policies may be designed to minimize the adverse effects of rice supply instability.

Although less than 5% of the world's rice is traded internationally, the world rice market and the policies of industrial nations remain an important determinant of national rice prices. IRRI will continue to monitor the world rice market and its implications for the Institute's research agenda (e.g., in long-term price forecasts and in grain quality). Irrigation and fertilizer investments will remain an important determinant of shifts in rice supplies. We will examine incentives to invest in irrigation, fertilizer, and other inputs, given the economic outlook for rice and the predictions for climatic change, and also analyze, in collaboration with IFPRI, the changing comparative advantage of rice and other crops to the extent that these will influence rice supplies.

Priority research within IRRI's production impact programs will include:

1. Aggregate assessment of the production impact of proposed and emerging technology and analysis of rice production and production stability by rice environment, by country, by region, and globally.
2. Forecasts of supply and demand for rice by country for alternative policy and investment scenarios, including evaluation of the impact of market prices on consumer groups and rice producers.

3. Assessment of how IRRI's and national program research priorities may shift as countries achieve self-sufficiency in rice, as the characteristics of international markets and prices change, and as rice production environments change.
4. Assessment of public policies designed to promote community operation in fields such as water management, IPM, and land conservation, and of steps taken to promote the efficiency of small-farm management.

Research in PA 302 will continue to build on the excellent cooperation developed with IFPRI and the Rockefeller Foundation. This cooperation will strengthen IRRI's capacity to conduct research in the areas of production instability, rice trade, and supply and demand projections.

303 Livelihood impact. The focus of IRRI's research in impact analysis is how advances in rice science affect the well-being of people. IRRI will continue to evaluate, through livelihood impact assessment, the income, employment, and equity consequences of new rice technologies and rice farming systems. In many cases, this will require the development of new methods or the adaptation of existing ones. Two identifiable outputs from a program in livelihood impact analysis are methodology development and quantitative evaluation of technological change on the livelihood of the poor, including possible differential impacts on members of the household.

Policy and institutional analysis is of central concern to livelihood impact assessment; national policies (e.g., price and trade policies, investment policy on irrigation, fertilizer pricing policy, and exchange rate policies) as they influence the consequences of new rice technology will be examined. Similarly, IRRI will seek to better understand how social institutions (e.g., tenure, farm size distribution, market access) influence the impact of rice technologies on the producers and consumers of rice, with particular concern for disadvantaged groups.

On the other hand, the Institute has less capacity and lacks the expertise to conduct nutrition- or health-related research. Therefore, IRRI must seek to cooperate with others with specific expertise who will take major responsibility for research in the nutritional and health-related aspects of new rice technology, including changes that may occur in the dynamics of vector-borne diseases with intensified rice production.

Priority research within the Institute's livelihood impact programs are:

1. Evaluation of the differential impacts of proposed and emerging technologies in favorable and unfavorable rice environments on the livelihood of rice producers and consumers.
2. Analysis of the impact of proposed or emerging technologies, policies, and institutions — and their interactions — on the livelihood security of small-farm households, women, landless households, and other disadvantaged groups.
3. Evaluation of the benefits and distributional impacts of alternative directions of IRRI's research at Los Baños and in collaboration with national programs.

As with PA 302, collaboration with the Rockefeller Foundation and IFPRI will expand IRRI's capacity to respond to these research priorities. Close collaboration with national researchers is also a key to the success of livelihood impact analysis.

Program integration

The interactive effects of socioeconomic and biophysical impacts can be determined only through long-term, carefully designed, multidisciplinary investigations. Methods for such research, which may emerge from an extension of existing on-farm cropping systems research methodology, will be developed and tested as a component of PA 300 activities. Assistance will be sought from those already experienced in conducting such macro-scale integrated research. Specifically, external funds have been identified to permit IRRI to bring together a panel of experts in late 1987 to map out with IRRI a research strategy and plan in Socioeconomic and Environmental Impact analysis.

VI. PA 400: Education and Communication

Program Area 400 consolidates education, communication, and library and documentation. Subprograms are as follows:

401 Training
402 Communication and publication
403 Library and documentation

A major contribution of IRRI to increasing the capabilities of national rice research programs is human resource development. Education and communication are strategies used to share new knowledge and skills in rice culture and related sciences with NARS.

The objective of IRRI's training and professional advancement programs is to create a cadre of well-trained and highly motivated scientists working on various aspects of rice culture and rice farming systems in developing countries. The kind and level of training programs are continuously revised to fit the changing needs of national programs.

More than 5,000 scholars and scientists have participated in IRRI's training programs since 1964. IRRI training programs can be broadly classified as a) research-oriented and b) applied research and extension-related; both are designed to assist national research and extension systems.

Many former IRRI alumni now work as national leaders in research and research management in their home countries. Their contributions toward the enhancement of rice production and the advancement of scientific agriculture have been recognized by the large number of national awards bestowed on them. Although a great deal of progress in training has been achieved, major challenges and opportunities remain. Recent advances in rice science and technology have made it necessary to diversify IRRI's training programs into new areas of instruction. The building of national rice farming research capabilities, of which training is an essential and important part, continues to deserve high priority.

The IRRI Academic Council was organized in May 1983 to serve as an advisory body on all matters relating to the academic and professional training of scientists associated with national programs that collaborate with the Institute on rice and rice-based farming systems. Its membership includes IRRI's Director General (Chairman); its Deputy Directors General; the Director of Training and Research; the heads of research departments and global research services; two senior scientists in IRRI cooperative country programs; the Presidents/Chancellors or nominees of UPLB, the United Nations University, the Association of Asian Agricultural Colleges and Universities, the Southeast Asian Regional Center for Graduate Study and Research in Agriculture, and the Asian Development Bank; the Resident Representative of the United Nations Development Programme; and five distinguished members nominated by the Director General of IRRI. The Academic Council has the following objectives:

- Review annually all training programs in the context of IRRI's training objectives, its existing training facilities, and the needs of national rice research and development programs.
- Review policies regarding the selection of participants for IRRI training programs, such as institutional affiliation, academic background, and English proficiency.
- Suggest guidelines for evaluating existing and proposed training curricula, including the preparation of training manuals and autotutorial modules.
- Review courses that can be transferred to national programs and suggest procedures for assisting national programs in their training courses.
- Recommend steps for promoting twinning arrangements between leading agricultural or other universities in rice-growing countries and IRRI in graduate and postgraduate training programs.
- Recommend measures that can help maintain a high degree of relevance and excellence in IRRI's manpower development programs.

These objectives are being implemented with the help of the following standing committees:

- Committee on Visiting Scientist, Postdoctoral Scientist, and Collaborative Research Scientist Fellowship Programs
- Committee on MS, Ph D, and Nondegree Research Fellowship Programs
- Committee on Extension/Production-related Training Courses
- Committee on Scholars' Welfare and Cultural Programs

The training programs of the IARCs were reviewed comprehensively by TAC in 1984. The review was generally complimentary and supportive of these programs, but recommended somewhat greater emphasis on the following points:

- Assist the developing countries in formulating manpower development plans. (This recommendation was also made by the International Conference on Education in Agriculture held at IRRI on 12-16 November 1984.)
- As much as possible, integrate, harmonize, and coordinate IARC training activities in individual countries. This may be feasible for such broad coverage subjects as farming systems research and IPM.
- Encourage cooperative training programs with national universities responsible for agriculture and related fields.
- Place greater emphasis on the transfer of certain production-related courses to national programs, and determine the feasibility of some of these national programs serving as centers of regional cooperative networks for these training courses.
- Monitor, evaluate, and follow up the work of alumni in their respective countries. The donors should support these activities. In appropriate cases, the IARCs should seek means to help their alumni to get started with their work on their return to their jobs after training.

The training priorities and strategies outlined here take into account these suggestions.

OBJECTIVES AND STRATEGIES

401 Training

The Training Subprogram Area has two concentrations: research-oriented programs and nondegree training.

Research-oriented programs

Included in this concentration are MS, PhD, visiting scientist and postdoctoral programs, and special research fellowships.

Rationale. MS and PhD degree training is important in helping national programs staff their research institutes with scientists from different research disciplines. Trained scientists help develop the appropriate material and technology that enhances the productivity of rice farming. Graduate study provides recipients with the ability to adapt and extend technologies to their national programs. To this end, IRRI has cooperative agreements with 24 degree-granting institutions around the world; this enables students to take coursework at the appropriate university and to conduct their research in conjunction with IRRI scientists.

As a general policy, MS students are encouraged to take their coursework at collaborating universities located in or near their home countries; PhD students enroll at universities offering a broader selection of more specialized courses. All students conduct their thesis or dissertation research under the guidance of IRRI scientists at IRRI or in other appropriate locations. This cooperative graduate training will increase in relative importance, particularly at the PhD level, as more and more national systems develop strong educational and research facilities for MS degrees.

The linkages with universities in developing countries and the acceptance of their university staff in degree programs are also of assistance in developing more effective research and training programs in NARS.

The visiting scientist program and postdoctoral fellowships are designed to enable senior researchers of national programs to pursue in-depth research on problems relevant to their home countries, using IRRI's facilities and in coordination with IRRI scientists. Frequently, Fellows come to IRRI to further investigate their own research findings.

Senior scientists who do not have the academic equivalent of the PhD degree are designated special research fellows and receive the same benefits as postdoctoral fellows. Young scientists from organizations in developed countries with which IRRI has collaborative research projects are designated collaborative research fellows.

Objectives

1. Advance national scientists professionally by enabling them to obtain their MS and PhD degrees and to learn modern research principles and techniques.
2. Contribute to the professional growth of postdoctoral and special research fellows and provide them with opportunities to

follow up their own findings or to conduct in-depth research on topics pertinent to their national programs using modern equipment and techniques.

3. Promote technology sharing between IRRI and the research, extension, and academic institutions of cooperating NARS.

Strategies

1. Ensure selection of scientists from the appropriate disciplines who will research topics that have high priority in national programs. Wherever appropriate, part of the research work should be conducted in the participant's home country.
2. Continue interaction and collaborative research with alumni after they return to their home countries.
3. Strengthen and expand agreements for collaborative graduate programs with many universities.
4. Conduct feedback and impact research with alumni and those responsible for human resource and program development in NARS.
5. Limit the selection of MS candidates from countries with facilities for the MS degree to relatively new research areas in which national programs lack the necessary facilities and expertise; accord high priority to PhD degree programs.
6. Encourage cooperative funding programs between NARS and IRRI. In certain countries, a trilateral memorandum of agreement (Department of Agriculture, agricultural university, and IRRI) is required to implement these programs.
7. Incorporate research management and scientific communication into the study program to provide students with well-balanced training in research, research management, and scientific writing.

Nondegree training. Included in this concentration are short courses, instructional resource development, training studies, and cooperative in-country training.

Short courses

Rationale. The primary aim of the nondegree training courses is to introduce national scientists to and update them on the latest advances in rice science and related disciplines. IRRI currently conducts 13 research, production, and support courses to train national scientists to be proficient in applying technological information and skills. Participants usually are chosen from among national staff who, upon completion of their training, will return to their home countries and enrich the reservoir of professional talent there.

The nondegree training methodology at IRRI is a blend of the academic and the applied: approximately half the instruction takes place in the laboratory or field. It is highly tutorial in that trainees conduct experiments and projects in small groups under the guidance of an adviser. Refinement of this methodology to further accentuate practical, problem-solving behavior is one goal of nondegree instruction.

The number of nondegree courses at IRRI has increased, reflecting an increasing demand for specialized courses and on-the-job training that stems from the expansion of research and support technology into more and more specialized areas. As IRRI's programs become increasingly specialized, the number of courses is likely to increase, with a decrease in the number of participants in each course. Concurrently, we can expect to see increased demand for conventional production courses from those national systems that are in the early stages of technological development. This means that IRRI will have a dual responsibility for training, in both upstream and downstream areas at the same time.

Objectives

1. Improve the proficiency of NARS scientists to conduct field research in the basic components of rice science, endeavoring to build a competent cadre of rice scientists.
2. Transfer basic production courses to those countries that have the necessary infrastructure to conduct in-country training.
3. Develop self-learning modules in basic production courses to serve as training materials at IRRI and in national programs.

Strategies

1. Select participants for basic production courses who have a direct role in production programs, with BS degree or equivalent qualification, and 5 years research experience. Priority should be given to those who, upon return to their home institutions, will have research and training responsibilities that parallel their training experience.

2. Give preference in the allocation of slots in basic production courses to participants from NARS in the initial stages of building a research base.
3. Transfer basic production courses to NARS with the requisite infrastructure to conduct in-country training, convening the courses at IRRI periodically as a means of in-service training for trainers from NARS. Also, maintain close liaison with these NARS to see that high quality is maintained in their in-country training courses.
4. Continue revising and updating course curricula to ensure their accuracy and relevance to national programs.
5. Devise a screening test to measure candidates' English proficiency.

Instructional resource development

Rationale. IRRI has a history of using programmed, self-learning technology. For 10 years, the Institute has packaged the content of various training programs into audiovisual sets (slides, cassettes, and booklets). During the last few years, use of self-learning training technology has been intensified by the establishment of an instructional resource unit dedicated to the production of instructional courseware.

Many national training programs have a paucity of training materials and, usually, lack the expertise and resources to produce them. Packaging training materials expedites the application of IRRI's training philosophy (applied, field-oriented, hands-on, problem-solving). It also assists in overcoming language barriers in the transfer of information and technology to other training programs.

A computer-generated program in courseware development has been funded by the International Development Research Centre (IDRC) of Canada. When completed, this project will greatly accelerate the translation, adaptation, updating, storage, and recall of training content and materials to assist in Institute training and in the transfer of training programs to NARS. It will act as a database to generate slide tape productions.

Objectives

1. Provide training materials for trainees at IRRI as well as in national programs. The latter urgently need such materials to enable instructors to offer systematic training using up-to-date technical information.
2. Facilitate self-learning options through modular instructional packages and copublication.
3. Increase the efficiency of resource persons through the use of programmed learning and performance objectives, to allow more time in the problem-solving areas of training experiences.
4. Generate a computer-based databank of training curricula and learning objectives, correlated to cognitive and psychomotor skills.

Strategies

1. Employ the educational principles of learning objectives, programmed self-learning, adult education, computer-aided instruction (CAI), and computer-managed instruction (CMI) to develop courseware.
2. Modify and adapt training materials to suit different agroecological conditions.

Training studies

Rationale. Training and technology transfer approaches should be subject to validation and the principles of accountability. The techniques, strategies, and results of educational activities should be examined to determine their value in meeting objectives set within the Institute's mandate and program plans, as they relate to client populations.

Educational methodologies are undergoing enormous change in response to rapidly developing techniques and hardware (particularly computerization). These tools are being adapted to IRRI's activities. Future adaptations should be authenticated and planned against a solid, scientifically collected database for efficiency and for cost/benefit control in program development a program of adaptive research on educational technology.

Objectives

1. Develop methodologies to assess in-country pretraining needs and posttraining impacts.
2. Evaluate techniques and methods of constructing learning modules and lessons in relation to learning domains and instructional styles.
3. Develop and evaluate CAI and CMI materials.
4. Develop a cost-accounting model for training programs.
5. Investigate social/psychological parameters and interrelationships that will help bridge

cultural differences among training populations.

6. Study the areas of culture-bound learning behaviors and visual literacy.
7. Correlate teaching/training methodologies with learning objectives, learning styles, culture-bound learning expectations, and personality types among the trainee population.
8. Validate the principles associated with programmed instruction, CAI, CMI, and adult education in the context of multinational training programs and the training transfer programs in NARS.

Strategies

1. Contract technical educational consultants to conduct in-house workshops.
2. Conduct a literature search in Conduit, ERIC, Psychological Abstracts, and other databases and journals.
3. Purchase and test off-the-shelf software for CAI/CMI courseware development.

Cooperative in-country training

Rationale. Much of the content taught in production courses is agroclimatically specific and could better be taught in-country wherever the NARS has the requisite training capabilities. Course transfer to NARS with these capabilities would use fewer IRRI resources and permit the development of new courses.

There is often an extended lag time between the development of a technology and its diffusion to the target population. The sharing of knowledge and skills between IARCs and NARS is no exception. Some major constraints that contribute to this time lag are:

- carrying capacity of training programs in international institutes,
- courseware to meet in-country requirements,
- language barriers,
- availability of appropriate training models,
- lack of reliable educational technology,
- transfer of human resources within NARS,
- absence of a critical mass of professionals in the training program,
- priority given and resources allocated to human resource development, and
- lack of research experience to adapt and refine training programs to changes in technology.

IRRI has embarked upon a program of sharing the information, concepts, and skills taught in its nondegree courses with in-country training programs. In this manner, the courses can be adapted to local conditions and language difficulties can be overcome, thereby accelerating the diffusion of technology. An eight-step shuttle training model to transfer courses has been successfully pilot-tested in Bhutan.

Several IARCs conduct cooperative research in many countries. It would be useful to organize joint IARC-NARS training programs, where appropriate, that pool the complementary strengths of all participating institutions.

Objectives

1. Facilitate the development of training courses in national programs.
2. Assist NARS in developing their capabilities to conduct their own formal nondegree courses.
3. Work jointly with NARS and other IARCs in developing an integrated training program for an entire farming system.

Strategies

1. Develop and implement cooperative projects to transfer IRRI courses to national systems, using the shuttle training model.
2. Evaluate the efficiency and acceptability of the shuttle training model.
3. Produce adaptable courseware for transfer to in-country programs.
4. Train human resources in NARS to be proficient in applying educational technology.
5. Develop model transfer teams composed of IRRI junior staff.
6. Extend the concept of shuttle training to those in national systems responsible for human resource development.
7. Develop computer-based courseware for the basic rice production course.
8. Refine the training and technology transfer course.

402 Communication and publications

Included in this Subprogram Area are the following concentrations: scientific publication, promotion of public awareness, copublication, and communication studies.

Scientific publication

Rationale. Research publication is vital to all scientists in PA 100, 200, and 300. IRRI has always considered the communication of its own research

a prime responsibility. Journals and books published in the developed countries are often too expensive for, or unavailable to, the scientists of developing countries whom we serve. The prices of such publications are, moreover, rising rapidly, making access to them all the more difficult.

Objectives

1. Support increased research publishing of the Institute through effective utilization of personnel.
2. Offset the rising costs of research publishing through the effective use of technological advances in publishing.
3. Ensure the widest availability of the Institute's research output through effective marketing and efficient distribution.

Strategies

1. Relieve the editorial load by a) contract editing, and b) dual imprint agreements with commercial publishers, in which the commercial publisher does editing and production and IRRI purchases copies at a reduced price for sale in the developing countries.
2. Continue to upgrade in-house typesetting and composition by combining the digital typesetter and graphics text organizer with scanning technology to produce artwork directly through the digital typesetter.
3. Substitute desktop publishing (with the laser printer) for typesetting on publications and some serials that do not require book quality composition.
4. Monitor developments in paperless electronic publishing through computer networks. (Our experience in the internal use of computers and high technology publishing will permit us to take advantage of any development in electronic publishing that will benefit the Institute.)
5. Participate in international and regional book fairs to promote IRRI books, identify potential publishers for dual imprint agreements, and set up international distribution centers. (These activities are aimed at increasing revenue to support research publishing from the contract printing revolving fund.)
6. Computerize inventory control and invoicing.
7. Refine the list of review journals and place new publications in the hands of appropriate reviewers.

Promotion of public awareness

Rationale. A strong, sustained public awareness program coordinated by the Director General is necessary to assure current or increased levels of funding and to provide the information climate to make media less prone to misinformation concerning IRRI and the CGIAR. The demand for materials to inform donors and policymakers will also increase with stiffer competition for tight funds.

Objective. Create an understanding of and a positive attitude toward IRRI and its programs among donors, policymakers, and the public in both developing and highly developed countries.

Copublication

Rationale. Language is a major barrier to the dissemination in developing countries of information on improved technology. It is difficult for an international research institute to publish in any language other than its working language. Although English is generally acknowledged as an international language of science, only 0.4 billion of the world's 4.3 billion people speak it as their native language. This means that materials published in English automatically bypass 90% of the world's population. Consequently, the results of the hundreds of millions of dollars invested in international agricultural research are available only to the top-level research community and government planners, who comprise the English-speaking segment of most non-English-speaking countries.

IRRI has developed the concept of copublication and has more copublication experience than any of the other IARCs, having copublished more works, in more languages, and in larger publication runs. IRRI also has policies and procedures in place for entering into copublication agreements and providing national programs with logistical and production support in their copublication efforts. Finally, IRRI has computerized records of almost 200 individuals and agencies who have translated or copublished translations of IRRI publications. These records help identify translators and copublishers of future publications in various languages.

These activities interface with PA 100, 200, 300, and 500.

Objectives

1. Identify titles emanating from Institute research that lend themselves to copublication, and through planning and design, facilitate their publication in non-English languages.
2. Define procedures that will enable copublishers to publish IRRI books of their selection in their native languages.
3. Provide copublishers, particularly those without the technical knowledge or resources, with logistical and production support in copublishing IRRI books of their selection.

Strategies

1. Work with IRRI authors at the planning stage of publication to ensure that works with copublication potential are written and designed in a manner that will move them easily into non-English languages.
2. Lend printing negatives, color separations, and reproducible artwork to copublishers who wish to publish IRRI books.
3. Arrange for typesetting or printing of copublished works at actual costs for copublishers without in-country capabilities.
4. Permit copublishers to adapt translated IRRI publications to meet local conditions; adaptations should be done, however, only by IRRI cooperators.
5. Waive royalties or payment on the copublication of translations of IRRI materials in Third World countries.
6. Identify funding agencies and write funding proposals for copublishers who do not have funds to support a copublishing venture.

Communication studies

Rationale. Communicating research knowledge and technology should be subjected to the principles of validation and accountability. The techniques, strategies, and results of communication activities should be examined to determine their value in meeting objectives set within Institute mandates and program plans, in the context of client groups. Communication methodologies are undergoing enormous changes in response to rapidly developing techniques and hardware (particularly computerization). These tools are being adapted to IRRI's activities. Future adaptations should be authenticated and planned against a solid, scientifically collected data base for efficiency and for cost/benefit control of program development.

Objectives

1. Map the diffusion of IRRI publications to target groups, both directly and through pass-along and library accessibility.
2. Examine the diffusion of IRRI research through national programs into extension programs to farmers, to provide insights into the shape and character of the research-extension information system.
3. Examine the channels and design of communications that promote awareness, knowledge, and acceptance of advanced technology.
4. Examine the copublication network and the evolving communication system associated with copublication.
5. Study the communication systems developing in association with collaborative national programs.
6. Develop procedures for designing communication toward specific objectives with specific audiences, building a base of knowledge about audience communication skills, expectations, and responses that can be applied to precise communication planning and message design (whether publication, audiovisual, video, or computerized).

403 Library and documentation services

Rationale. To complement its strong research and training programs, the Institute should maintain its reputation as the world's primary repository of rice literature. Its collection should be useful to scientists and scholars doing research on rice and rice-related topics.

Objective. Maintain and operate an information center and library to provide efficient and effective worldwide service to rice scientists and scholars, following the Institute's mandate.

Strategies

1. Acquire literature on the subject of rice from books, periodicals, theses, reports, and leaflets in all languages and in all editions. Only rice publications will be acquired in depth, but collections in the following areas will be strengthened: socioeconomic and environmental impact, Asian farming systems, and women in agriculture.

2. Put order and logic into acquisitions through classification and cataloging.
3. Provide reader services through an open-stack system; reference system; current awareness service; translations of at least 23 languages used in rice literature; publication of bibliographies, directories, theses, dissertations, and acquisitions lists; document delivery backup services; clipping service; and a computerized rice literature search service.

VII. PA 500: International Collaboration

A major role of IRRI in recent years has been to foster the growth of a global family of rice research institutes and scientists dedicated to the cause of improving the productivity, profitability, stability, and sustainability of rice farming systems. Over the years, several pathways of collaboration have been developed and tested (Table 8). During the last 25 years, nearly 5,000 rice scientists from 78 countries have been trained at IRRI. This area of IRRI activity is dealt with under Program Area 400. Several countries in Asia, which had only a few trained personnel to undertake problem-solving rice research at the time of their independence, now have reasonably staffed and equipped rice research institutions. Many IRRI alumni occupy important positions in national agricultural research and development systems and universities.

IRRI operates several global research services which help to strengthen the bonds of collaboration and the sharing of knowledge and material among rice scientists. Notable among these is the International Rice Germplasm Center, which strives to maintain for current and future use a representative sample of genetic variability in rice, the product of thousands of years of natural evolution and human selection.

The impact of 25 years of partnership with NARS was chronicled in June 1985, on the occasion of IRRI's 25th Anniversary (IRRI: 25 Years of Partnership). This partnership has been symbiotic in nature, resulting in considerable synergy in terms of benefits from the available scientific and financial resources. The productive partnerships between NARS and IRRI indicated in Table 8 have played a catalytic role in the progress made during the last 25 years in improving the production and productivity of rice in irrigated and favorable rainfed areas.

IRRI's research focus is moving now into the more difficult climatic, soil, and social environments. Ecologically underprivileged areas typically have low rice yields, either because of moisture scarcity or surplus or because of soil toxicities and deficiencies. Such ecologically underprivileged areas are usually inhabited by economically disadvantaged farming families. If IRRI is to carry out meaningful research for these environments, research work must be done in partnership with

Table 8. Pathways of cooperation between IRRI and other scientists and institutions.

Pathway	Examples
Research services	IRGC, BNF germplasm
Networks	IRTP, INSFFER, ARFSN
Country programs	Resident IRRI scientists Scientist-scientist collaboration
Collaborative research with NARS	Hot spot screening Shuttle breeding Farm machinery
Collaboration with advanced research institutions and other IARCs	Organizations (USAID, IRAT, GTZ, ODA of U.K., etc) Universities and institutions International centers (IITA, WARDA, ICIPE, etc.) Individual scientists
Training and technology transfer	Los Baños In-country
Knowledge sharing	Seminars, monitoring tours Bibliographic services Publications

NARS at the epicenters of the problem areas. In other words, part of IRRI's core research must be carried on outside IRRI's main location at Los Baños in the Philippines. This will call for new forms of partnership between NARS and IRRI and new patterns of linkages among allocations in IRRI's core budget and programs for well-defined target environments.

Similarly, there is explosive progress today on many frontiers of science and technology (e.g., biotechnology and genetic engineering, micro-electronics and computer sciences, satellite imagery and educational technology). If IRRI is to serve as an effective bridge between advanced laboratories working at the frontier of science and developing institutions in cooperating NARS, new forms of trilateral and multi-trilateral institutional linkages will have to be developed.

As we look toward the 21st century, it is obvious that new patterns of collaboration and new methods of core research organization will have to be developed. PA 500 aims to consolidate and expand the gains already made through existing patterns of collaboration. At the same time, it seeks out and strives to develop new bonds of collaboration, based, on the one hand, on the changing strengths and needs of NARS and, on the other, on the changing research priorities of the CGIAR system and rapid developments in science and technology.

Four sub-program areas will be linked to appropriate budget allocations.

501 Collaborative research and training
502 Strategic research cooperatives
503 Global research networks
504 Regional and country programs

501: Collaborative research and training

IRRI's scientific staff spend considerable effort in collaborative research and training activities with their counterparts in NARS and with scientists in advanced institutions and universities, in both developed and developing countries. Usually, these programs are implemented through three major types of financial arrangements: a) collaboration in which individual scientists undertake a joint research program based on shared interests and costs; b) cost-sharing collaboration in which IRRI and the concerned scientific institution share the costs of the collaborative research projects under a Memorandum of Understanding; c) special collaborative research projects financed directly by donors. A few examples of these types of collaboration are given below.

Research project	Collaborating institution/country	Complementary relationsiop to core research
Collaboration between individual scientists		
Technical and price efficiency in rice	National U of Singapore	As margins decline, the need for increased efficiency in resource use in rice production increases
Molecular properties of tropical rice amylose and amylopectin	Kagoshima U Japan	Grain quality
Screening for varietal difference in feed value of rice straw	TDRI UK	Nutritional value of residues and by-products
Chemical basis of resistance to BPH	Western Reg Res Center USA	Varietal resistance to insect pests
Genetics of blast resistance in indica ricos	NIAS, Tsukuba Japan	Complements IRRI's blast genetics work in GEU program
Cost sharing collaboration		
Productivity of rice-wheat systems in South Asia	Pakistan	Identification of factors influencing productivity in rice-wheat systems in South Asia.

Research project	Collaborating institution/country	Complementary relationship to core research
Simple technique to measure NH_3 volatilization and denitrification losses in lowland rice fields	CSIRO ACIAR IRRI Agronomy	Management of soil and fertilizer nitrogen
Green manuring in rice-based cropping systems	GTZ/ CIRAD	Assessment of the potential of stem-modulating *sesbania rostrata* and other species.
Microbial agents for control of BPH, GLH	Boyce Thompson Institute, USA	Biological control of insect pests
Upland rice breeding adverse environment	IRAT, France EMBRAPA, Brazil WARDA, IITA, CIAT	Rice breeding for rainfed upland areas
Rice tungro collaborative project	Bangladesh India Indonesia Malaysia Sri Lanka Thailand	Varietal reactions to tungro virus agents and the vector leafhopper to look for stable resistance to tungro and to elucidate virus strain and vector "biotype" problems.
Physiology of deep water rice	ACIAR and U of Western Australia	Regeneration of tissue culture materials and training for Thai scientists working on deep water rice and submergence tolerance.
Data management system for on-farm trials	MAF, Philippines	On-farm research methodology
Special Project Funding Women in rice farming	UPLB, MAF IPC, CLSU	Develop mechanisms by which women's roles and welfare will be considered at appropriate stages of technology development and extension. Complements IRRI's constraints and consequences studies
Training course on editing and publishing	Toronto U Canada	Initiated to develop trained editors and information specialists who will publish and disseminate scientist's information to extension agents and farmers.
Rice Abstracts	CAB United Kingdom	Enables libraries of third world countries to receive complementary subscriptions to rice abstracts.
Monoclonal antibody research	USAID	Monoclonal antibodies produced in collaboration with ATCC will be applied to research on rice virus epidemiology at IRRI and the national programs.
Hybrid rice research	Tuscia U Viterbo, Italy Hybrid Rice Institute, Changsha, China	Complements IRRI research on hybrid rice, in which hybrid seed production is a major challenge. A number of seed production problems need to be resolved in the tropics before this technology can be recommended in countries outside China.

Research project	Collaborating institution/country	Complementary relationship to core research
Studies on breeding of rice varieties resistant to pest and disease, especially to bacterial leaf blight (low input project)	MAFF, Japan	To develop lines resistant to pests and disease; to decrease the use of pesticides in paddy cultivation.
Varietal improvement of legumes for rice-based cropping systems	Institute of Plant Breeding, UPLB	To identify varieties of soybean, peanut and mungbean. Selection and testing cultivars for rice-based cropping pattern.
Significance of organic materials on paddy soils	U of Hamburg	Effects of straw and water management on soil chemical properties. Understanding organic matter dynamics is important for nutrient kinetics, fertility conservation, soil health, and integrated nutrient supply. Enables IRRI to implement field studies with ^{14}C-labeled organic substrates.
Water and nitrogen use of legumes following rice	U Reading, United Kingdom	Tillage, water relations, and yields for legumes following rainfed lowland and upland rice
Removing soil-structural constraints to the production of maize and legumes following rice	U Minnesota USA	Seeding, crop establishment, and tillage for legumes following rainfed lowland rice

These represent just a few examples of collaborative research; every department at IRRI undertakes a wide variety of such collaborative work with NARS and with universities around the world.

As has already been emphasized, increasingly IRRI may have to undertake core or core-related research in countries which are most representative of specific target environments. For example, upland rice research is best undertaken at suitable locations in Indonesia and India in Asia, Ivory Coast in West Africa, and Brazil in Latin America. Research on deep water rice is best done in collaboration with NARS in Thailand, Bangladesh, Burma, India, and Vietnam. For rainfed lowland rice, northeast Thailand provides soil and climatic conditions representing a large extrapolation domain. To undertake such core or core-related research in association with an appropriate national research institute, suitable provision will have to be made in IRRI's core projects.

A good example of cooperative training in upstream areas is provided by the CABO-TPE-IRRI collaborative training program in Computer Simulation Modelling (see PA 400).

502: Strategic Research Cooperatives

Advanced institutions, strong national research systems, and IRRI can jointly organize strategic research programs whose benefits will transcend the political frontiers of a NARS. This will call for the formation of strategic research cooperatives, with the participation of two or more countries and institutions. A good example is the research cooperative now being organized to deal effectively with adverse soils. This cooperative will involve joint research by IRRI and Indonesia in peat soils, IRRI and Thailand and Vietnam in acid sulphate soils, IRRI and Sri Lanka in soils with iron toxicity, and IRRI and India and Pakistan in soils affected by salinity and alkalinity.

The Rice Genetics Cooperative supported by the Rockefeller Foundation represents another kind of research initiative with great potential for beneficial impact. It involves tapping the upstream research capabilities of advanced institutions for solving downstream problems. The Rice Genetics Cooperative consists of three major streams of activities: a) research on basic rice genetics, including the construction of linkage maps based

on both conventional and molecular techniques; b) standardization of methods for DNA transfer across sexual barriers; and c) standardization of cell and protoplast culture techniques which can help regenerate whole plants from protoplasts/cells containing the desired gene combination.

This cooperative brings a wide range of institutions and expertise together to search for breakthroughs in the improvement of yield, quality, resistance to pests and diseases, and tolerance of soil and climatic stresses. Research cooperatives of this kind involving institutes from both developed and developing countries provide an effective conduit for sharing the benefits of recent scientific breakthroughs among developed and developing countries.

503: Global research networks

In the broadest sense, networks link individuals and institutions that share a common purpose and focus. Networks were initiated as a structured mechanism for sharing genetic materials, expertise, and research methodologies. IRRI plays a coordinating role, facilitating organized collaboration among all institutions and countries interested in rice improvement. Recognizing the merits of the network approach in accelerating the development and transfer of technology, IRRI initiated international networks in the mid-1970s in the important research areas of varietal improvement (IRTP), nutrient management (INSFFER), and rice-based farming systems (ARFSN).

The functions of these networks are:

- International Rice Testing Program (IRTP) a mechanism for the exchange of elite rice germplasm among scientists in different countries for evaluation and utilization in their given environments. IRTP has been discussed previously as PA 113, under Genetic Improvement (PA 100).
- International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) a collaborative effort aimed at increasing fertilizer use efficiency and at improving and maintaining the fertility of rice soils through integrated nutrient management. INSFFER was discussed as part of PA 201 under Crop and Resource Management (PA 200).
- Asian Rice Farming Systems Network (ARFSN) an approach designed to identify more productive rice-based farming systems for small-scale farmers in the different countries of Asia. The major aim of this network is to increase farm income and on-farm employment on a sustainable basis from the land, water, labor, and credit resources available to a farming family. ARFSN was discussed in some detail as PA 206.

These networks are closely linked with IRRI's central research thrusts, and operate in the following ways:

- Exchange information to facilitate the sharing of ideas, methodologies, and research results and provide a mechanism to feed field-identified research issues back to NARS and IRRI and to feed solutions to these problems forward.
- Provide opportunities, through meeting and monitoring tours, for participating countries to jointly plan research activities and analyze and interpret results.
- Undertake collaborative research in which participating countries jointly plan, implement, and monitor research and share experimental material and data, often following a common research format to simplify comparison of results. Coordination is provided by IRRI to facilitate efficient and timely distribution and interchange of materials among the participating national programs.

504: Regional and Country Programs

The wide range of variability in national rice yields is shown in Table 1. The nature of the help IRRI should extend will depend on the nature of the development of a country's research, training, and development programs. This sub-program area is designed to help IRRI respond to the specific needs and problems of a country. IRRI has formal or informal relationships in both research and training with nearly all the rice growing countries in the world. In certain geographical areas, where other IARCs exist, IRRI plays a complementary role, achieved by positioning an IRRI Liaison Scientist at another IARC. The IRRI liaison scientist for West Africa, located at IITA in Ibadan, serves as a link between IRRI, IITA, WARDA, and West African national programs. Similarly, IRRI's liaison scientist at CIAT in Cali, Colombia, helps to establish linkages with rice growing countries in Latin America. IRTP representatives in Tanzania and Dominican Republic serve East and Southern

Africa and the Caribbean region. Invariably, the help given by IRRI on a regional basis involves supplying germplasm and breeding materials and providing training opportunities.

Country-specific programs usually are developed in the following manner:

1) Authorities of the concerned NARS request IRRI either to send a mission or to receive a mission to discuss areas of collaboration. Obviously, when expressing interest in actual collaboration with IRRI, the government of the country concerned would have made a major commitment to improving rice production in the country.
2) Through discussions among concerned scientists, areas of research and training are identified where the concerned NARS perceives a critical gap in internal need and competencies and where IRRI feels it can make a useful contribution.
3) Once a detailed cooperative research and training work plan is formulated, a Memorandum of Understanding is signed by the Director General of IRRI and the head of the NARS. The memorandum normally is an umbrella agreement, with provision for the joint preparation of detailed annual or biannual work plans by the collaborating scientists. In the case of large rice growing countries such as China, India, Indonesia, and Thailand, annual work plan meetings are held, either at Los Baños or in the country concerned, to develop detailed research blueprints that spell out what each participating institution will do during the year. In the case of countries with smaller rice areas, the work plan may be finalized by correspondence or during visits of scientists. Progress on the agreed work plan is monitored by the IRRI scientist/director having the primary responsibility for overseeing its implementation.

Support for such country programs largely comes from special projects funding from either a single donor (e.g., CIDA in Burma, USAID in Egypt and Madagascar) or a consortium of donors (e.g., Australia, Canada, USAID, and Ford Foundation in Bangladesh).

IRRI's collaboration is usually in research and training. Occasionally, IRRI may be invited to help in planning the development of a national rice research institute. IRRI played a supportive role in the development of the Bangladesh Rice Research Institute at Joydebpur and of the China National Rice Research Institute at Hangzhou.

The following examples illustrate how IRRI strives to achieve an appropriate match between the needs and aspirations of a NARS and the capacities of IRRI to fulfill them:

China. China is the world's largest grower and consumer of rice. China and IRRI develop a detailed cooperative research plan each year, at a special meeting of the scientists actively involved in such research. Research collaboration meetings are held alternately in China and at IRRI. IRRI has Memoranda of Understanding with the Chinese Academy of Agricultural Sciences, the Chinese Academy of Agricultural Mechanization Sciences, and the Chinese Academy of Science. Wide ranging collaboration based on these memoranda exists in rice genetics and breeding; hybrid rice research, including the economics of hybrid rice; farm machinery; crop production; soil health care; and germplasm collection and conservation.

In addition to assisting China to develop a national rice research institute in Hangzhou, IRRI actively participated in the design and development of a National Plant Genetic Resources Conservation Center in Beijing. A large number of Chinese scholars are trained at IRRI. In addition, China, in collaboration with IRRI, is hosting training programs in hybrid rice and azolla application for the benefit of other rice growing regions. A parttime liaison scientist helps IRRI develop and monitor the collaborative research.

India. India has the largest area in rice, but ranks second after China in production. The conditions under which rice is grown in India vary greatly. Some parts of India, like the Punjab and northwest India, have high average yields. Others, particularly some states in eastern India, belong to the Group IV yield category. ICAR and IRRI scientists work at testing a wide range of material for diverse growing conditions and resistances to pests and pathogens. In addition, there is extensive germplasm exchange. India participates actively in the three global research networks. India also provides coordinating facilities at Chinsurah in West Bengal for an ADB-supported regional integrated pest management project for deep water rice covering Bangladesh, Burma, Thailand, and Vietnam.

A formal Memorandum of Agreement exists between IRRI and the Indian Council for

Agricultural Research. Joint work plans are developed during the annual workshops of the All-India Coordinated Rice Improvement Project. An IRRI liaison scientist is located in New Delhi.

Indonesia. Indonesia is the world's third largest producer of rice. Within a ten-year period, the nation has moved from being the world's largest rice importer to self-sufficiency. Over the past 15 years, IRRI-Indonesia cooperative research has evolved into true collaboration. Under the Memorandum of Understanding, priority is given to genetic evaluation and utilization and resource exchange, upland rice, rice-based farming systems, water management, and farm machinery development and to increasing the technology base through training, graduate studies, nondegree attachments to IRRI, conferences and workshops, and exchange of technical information and publications.

Indonesia hosted the 1985 Upland Rice Research Conference, which has led to further collaboration in work on blast disease and management of acid upland soils. This collaboration may lead to the establishment of a major regional center in Indonesia to help accelerate increasing and stabilizing rice yields under upland conditions in Asia.

Another example of recent Indonesia-IRRI collaboration is the development of integrated pest management (IPM) strategies for rice. This project, in addition to identifying economic threshold levels for pests, involves a broader, systems approach to the management of pests, particularly BPH, within a context of varietal management and crop cultural practices.

Bangladesh. Wide-ranging collaboration exists between Bangladesh and IRRI. Until recently, four IRRI scientists were located in the Bangladesh Rice Research Institute; starting in 1987, there will be two resident scientists. The next phase of BRRI/IRRI collaboration will concentrate heavily on research and training activities undertaken jointly by scientists of both institutions. IRRI and BRRI scientists are giving greater emphasis to rainfed lowland rice and deep water rice.

Burma. Burma has been a traditional rice exporting nation. However, until the mid-seventies, yields had stagnated. In the initial stages of Burma/IRRI collaboration, considerable emphasis was placed on improving yield per hectare. Thanks to the steps taken by the government of Burma to enable farmers to adopt new technologies, both production and productivity have risen since 1979. IRRI also participated in the development of a rice research and training center at Yezin. Three resident scientists were located in Burma with funds provided by CIDA.

In the current phase of collaboration, which began in 1986, the emphasis is being placed on yield, pest and disease resistance, and quality. Rice-oilseed crop rotation has been given importance because of the large edible oil imports now necessary to meet consumer demand within Burma.

Egypt. On the basis of a recent review of progress made by Egypt in enhancing the productivity and profitability of rice farming systems, the following areas were identified for collaboration during 1987-91:

- development of high yielding, disease-resistant varieties combining desired agronomic and grain quality features for the Delta;
- development of high yielding, short-duration, and water use-efficient varieties, as well as an appropriate package of practices, for the New Valley;
- development of techniques for growing floating rice in Lake Nasser;
- establishment of appropriate relationships with the Egyptian seed industry; and
- organizing necessary training programs.

In view of the excellent infrastructure developed at Sakha for rice research and training, Egypt and IRRI plan to cooperate in offering training programs for scientists from other countries with similar rice growing ecologies (i.e., arid, irrigated).

Republic of Korea. Korea and IRRI cooperate in developing rice varieties with tolerance of cold temperature and resistance to blast. In addition, there is active collaboration on the development of hybrid rice and the application of tissue culture techniques in rice improvement. IRRI provides Korean rice scientists with facilities at Los Baños during the winter months for off-season multiplication of breeding materials, including breeder seed. Cooperation between Korea and IRRI in indica-japonica crosses has led to the development of some outstanding hybrid varieties.

Thailand. In Thailand, the largest rice exporting nation in the world, grain quality is extremely important. Because of the prevailing low international prices for rice, there is no incentive for farmers to plant higher yielding varieties. Cooperation with Thailand is related to breeding improved varieties for deep water and rainfed

lowland conditions. Under a formal Memorandum of Agreement between IRRI and the Ministry of Agriculture of the Government of Thailand, an IRRI core scientist (agronomist) works in Thailand and serves as IRRI Liaison Scientist.

Kampuchea. A formal agreement exists for collaboration between Kampuchea and IRRI. An IRRI mission which traveled in Kampuchea early in 1986 identified priority needs as: a) training a minimum number of essential research workers, who will then screen varieties and develop improved management practices; b) providing germplasm and breeding material; and c) organizing on-farm testing programs.

Madagascar. The Madagascar-IRRI project is part of the government's strategy to reach rice self-sufficiency by 1990. During the 2-1/2 years of the Madagascar-IRRI collaboration, a Malagasy rice research team has been formed within the National Center for Applied Research on Rural Development (FOFIFA) and a national rice research station constructed. In addition to IRRI's resident team leader/agronomist and plant breeder, IRRI scientists work with Malagasy scientists on specific aspects of rice development and management.

The collaborative rice research program focuses on the integration of plant improvement and crop management to develop systems of rice production adapted to the needs and opportunities of farmers living within the highly diverse rice growing environments of the high plateau (1000-2000 m), the middle highlands (700-1000 m), and coastal regions. Training at IRRI and within Madagascar is an important component of the project.

Pakistan. Rice yields in Pakistan have stagnated, partly due to problems of salinization in the major rice tracts of Sind and Punjab. Pakistan and IRRI have developed a strong cooperative program in breeding for salinity tolerance. A second productive area of collaboration is developing high quality rice varieties to replace the first-generation modern rices now grown extensively in southern Pakistan. Pakistan rice research institutes and IRRI collaborate actively in farming systems research; one focus is evaluating factors limiting on-farm yields of rice, another is a broader study of opportunities to increase the profitability of rice-wheat cropping systems.

Host Country Collaboration

While international collaboration is the major pathway to achieving success in converting IRRI's mandate into production gains, collaboration with the Philippine national agricultural research and educational system is intimate and multi-faceted. Almost from its inception, IRRI, located on the campus of the University of the Philippines at Los Baños (UPLB), has undertaken joint training programs leading to the awarding of M.S. and PhD degrees by UPLB.

The Philippines had not had a separate rice research institute. In 1986, the Philippine National Rice Research Institute (PhilRice) was set up at Los Baños. PhilRice and IRRI have entered into a Memorandum of Understanding for developing mutually beneficial collaboration. Ongoing collaboration with universities and research institutes in the Philippines will continue to be strengthened.

In 1982, a joint Ministry of Agriculture and Food/IRRI Technology Transfer Workshop was initiated to identify major research problems in the 12 regions of the Philippines. Such technology transfer workshops are held twice a year, once before the wet season and once before the dry season. Other areas of collaboration include participation as desired by MAF or UPLB of IRRI staff on national committees and working groups and joint training and industrial extension activities with bilateral donor support.

These examples only indicate the wide spectrum of collaborative relationships existing between NARS and IRRI. The relationships are dynamic in structure and content, emphasizing the twin principles of symbiosis and synergy.

Resources Allocated to Collaborative Research

Staff at IRRI headquarters were requested to estimate the time they allocate to collaborative research activities (Table 9). On the average, approximately half of all scientist time is allocated to IRRI-identified research activities and half to collaborative research and training activities. Equal time is now allocated by IRRI scientists to collaborative research and training and to country and regional programs (13%). Seconded and special project staff spend a larger proportion of their time on collaborative research and training programs (33%) than on country and regional program activities (less than 10%). The average for network activities across all IRRI scientists is 10%, but this figure is misleading; scientists with specific network responsibilities spend more than 80% of their time on these activities, the average time allocation of other staff to network activities is about 5%.

Overall, scientists do not predict major shifts in

Table 9. Present and projected balance at IRRI scientific efforts in scientist years (SY) allocated to collaborative and headquarters activities.

	IRRI senior staff				Seconded/special projects				Combined			
	Current		Proposed		Current		Proposed		Current		Proposed	
	SY	%	SY	%	SY	%	SY	%	SY	%	SY	%
IRRI headquarters	27.6	51	25.0	46	5.4	54	5.2	52	33.0	52	30.2	47
Collaborative Research and Training	7.1	13	8.5	16	3.3	33	3.4	34	10.4	16	11.9	19
Research Networks	5.3	10	5.6	10	0.5	5	0.6	6	5.8	9	6.2	10
Country and Regional Programs	7.0	13	7.9	15	0.6	6	0.9	9	7.5	12	8.7	14
Unassigned	7.0	13	7.0	13	0.3	3	0.0	0	7.3	11	7.0	11
Total	54	100	54	100	10	100	10	100	64	100	64	100

time allocated to collaborative research activities. But the time allocated to headquarters activities may fall slightly (from 52 to 47%). This reduction will permit small increases in collaborative research and training (from 16% to 19%) and in research network (from 9% to 10%) activities.

VIII. PA 600: Research Support Services

The multidisciplinary nature of IRRI's research programs calls for intensive interdepartmental and interscientist collaboration, which generates a wide range of needed research services, from standard and routine tasks (such as analytical services and weather-report services) to activities requiring special expertise and technology (such as the development of database systems). IRRI's research services are organized as formal service units (usually for standard and routine services utilized by a large number of scientists) or are integrated within an existing research department where the bulk of the needed expertise resides (usually consultancy and methodological development services).

To utilize resources with maximum efficiency, economy, and speed, services that increase research capacities by taking over routine work and that improve research quality by broadening expertise must be provided. Research services provide an important pool of special expertise and technology that is available on request to all scientists, regardless of their field.

The research services not only have helped IRRI achieve its goals, they have also opened up research opportunities and have become a prerequisite of research activities. They are also a mechanism to further strengthen the multidisciplinary collaboration of IRRI scientists.

To meet their objectives, IRRI's research services develop strategies that allow them to respond to and remain relevant to changing research needs and program goals.

The following research services have been established at IRRI:

601 Experimental Farm
602 Phytotron
603 Analytical Service Laboratories
604 Pesticide Residue Laboratory
605 Seed Health Unit
606 Environmental Data Service
607 Computer Center
608 Database Services
609 Statistical Services
610 Information Services

601 Experimental Farm

Rationale. Scientific field experiments in agriculture must be established under fully controlled, monitored, and standardized conditions. An experimental research farm with appropriate facilities and management is often the key to progress in agricultural science.

IRRI's experimental research farm in Los Baños has 177 ha of irrigated lowland, 87 ha of upland, and 10 ha of rainfed land. Each season all the research departments of the Institute conduct field experiments in support of PA 100, 200, 300, 400, and 500 goals.

To utilize resources with maximum efficiency and to ensure that farm operations meet the needs of the scientists, centralized management of farm service is essential.

Organization. The Experimental Farm has its own budget, facilities, and staff. An Advisory Committee of senior scientific staff members recommends policies and guidelines for operation. The Advisory Committee is chaired by a Deputy Director General. Two major sections comprise the Experimental Farm: Grounds and Rat Control and Experimental Farm Operations.

Principal activities. Maintenance of IRRI's grounds and research farm and operational farm services to support the research departments in conducting field experiments are the major functions of the Experimental Farm.

Crop management. On request of scientists, the Experimental Farm becomes responsible for land preparation, planting, pest control, weeding, harvesting, and drying of crop experiments. Routine work is done by laborers employed permanently; in times of high demand, contract laborers are hired. When field operations require draft animals, those also are hired.

Supply of agricultural chemicals. The Experimental Farm provides research departments with fertilizers and pesticides. Handling and storing pesticides requires special attention to comply with legal requirements and safety standards. On request, experimental plots are treated with pesticides by trained staff of the Experimental Farm. The

Experimental Farm supports the Entomology Department by surveying insect populations on the research farm.

Irrigation. The Experimental Farm maintains and operates the irrigation facilities (deep wells, reservoirs, pipes, channels, drains, pumps) on the farm. Water is supplied to experimental plots in the lowland and upland areas as requested by scientists. Irrigation water quality from most of the deep wells on the farm is poor because of geological conditions. Irrigation with water from deep wells has increased alkalinity, salinity, and boron content of the soil, resulting in nutrient imbalances and yield declines. Measures must be taken to improve irrigation water quality and to improve or maintain soil conditions on the farm.

Crop drying. The Experimental Farm provides drying facilities for all crops harvested from the farm, as well as those harvested from off-site trials.

Seed multiplication. The Experimental Farm handles seed multiplication, especially if large quantities are required by national agencies.

Grounds and farm maintenance. Maintaining and improving the infrastructure of the farm so that resources are utilized with maximum efficiency and effectiveness is a primary activity of the Experimental Farm.

Training. In cooperation with the Training and Technology Transfer Department, the Experimental Farm provides special training programs for research station managers.

Strategies. Shifts in program emphasis affect the services requested from the Experimental Farm. An increased focus on less advantaged environments implies the provision of or simulation of such environments, especially with respect to the soil component. For projected environmental studies, a special lysimeter and other sophisticated simulation equipment might have to be installed.

Special concern must be given to monitoring, conserving, and, if necessary, improving soil and environmental conditions on the farm to maintain a vital base for high quality field research.

Because of increasing demands for irrigated lowland fields, the growing need for upland and rainfed areas could be met only by leasing additional land adjacent to IRRI. There is no chance of converting lowland into upland or rainfed fields. A special upland/rainfed research farm at a location with representative environmental conditions will become essential with intended program shifts.

602 Phytotron

Rationale. Since its installation in 1974, the Phytotron has increasingly contributed to IRRI's research program. Varieties and lines identified through the use of Phytotron facilities have been used for direct testing in the field and as donor parents in the breeding program.

The rice germplasm collection has been screened in the Phytotron for cold tolerance at different growth stages. Many breeding materials have been screened for high temperature tolerance, drought resistance, salinity tolerance, and aluminum and boron toxicity. Some of these varieties or lines are now being tested in the field.

The laboratory has provided optimum conditions for maintaining the azolla collection and for growing rice plants regenerated from anther cultures.

The thrust of IRRI programs toward improving technology for adverse environments, such as temperature, soil stresses, insects, and diseases, requires that those environments be studied and defined in the Phytotron. The present biotechnology thrust also will require rigid environmental control.

Organization. The Phytotron, administratively attached to the Plant Physiology Department, has its own budget, facilities, and staff. An Advisory Committee of senior staff members recommends policies and guidelines for operation.

Objectives

1. Strengthen rice research on adverse environments and related issues by increasing the precision and reproducibility of simulated agroclimatic environments.
2. Provide controlled environments separately and at any time of the year of climatic factors that are interrelated in the field.
3. Provide controlled environment facilities for the biotechnology program.
4. Provide non-Phytotron users with access to cold rooms, ovens, leaf area meters, etc.

Strategies. In order to sustain the efficient operation of the 12-year-old Phytotron, the entire facility should be improved or upgraded, as follows:

1. Acquire a third generator as a backup to the two existing ones, which are just adequate for the Phytotron during power interruptions, but which are also connected to four other buildings.
2. Sequentially replace the existing growth rooms.
3. Computerize the operation as much as possible

to decrease long-term maintenance costs.

4. Continue to staff the Phytotron 24-hours a day.

603 Analytical Service Laboratories

Rationale. Chemical data are essential interpretative tools and chemical analysis is of paramount importance in soil and plant research. At IRRI, research programs in soil fertility, plant nutrition, and crop production routinely require analysis of soil, plant, and water samples. However, some programs that rely heavily on such analytical data, such as rice-based farming systems, were established without laboratory support. To facilitate cost-effective chemical analysis of samples generated by the research programs, a central research support service unit was established in 1977. In 1981, the unit was reorganized to include mass spectrometric (^{15}N) analysis and radioisotope handling facilities and was renamed the Analytical Service Laboratories (ASL). With centralization, standardization of analysis methods, quality control, and expeditious processing within the capacities of the laboratories were facilitated.

Organization. ASL, administratively attached to the Department of Soils, has its own budget, facilities, and staff. An Advisory Committee of senior staff members recommends policies and guidelines for operation.

Three sections comprise ASL: the Chemical Analysis Laboratory (CAL), the Mass Spectrometry Laboratory (MSL), and the Radioisotope Laboratory (RIL). CAL provides a wide range of analyses of soil and plant samples, as well as of other samples. MSL runs $^{15}N/^{14}N$ ratio analyses on samples that have been labelled with ^{15}N. RIL provides special laboratory facilities for labelling, handling labelled samples, counting activity, personnel dose monitoring, and radioactive waste disposal.

Principal activities. Routine analysis is the major function of ASL. Most soil and plant research requires standard analytical data on the chemical composition of soil, plant, and water samples. This is particularly true of Crop and Resource Management (PA 200). Even departments with their own laboratory facilities (Agronomy, Soils, Cereal Chemistry) routinely use ASL for such activities as nitrogen analysis in rice grain quality studies, silica analysis in straw quality studies, and soil and plant analyses in soil fertility and soil problem studies. ASL support of the various network activities requiring analytical data for samples coming from a wide range of countries and environments should not be underestimated. Using standard analysis methods eliminates inter-laboratory variations and simplifies data interpretation.

Rapid technological developments, resulting in emerging methodologies, and the shift in research priorities, resulting in changing research needs, will make refining and standardizing new analytical methods an essential function of ASL. Similarly, the large number of samples requiring analysis necessitates efficient processing. The search for high-quality, cost-effective, and rapid analytical methods will continue. Automation and computerization will help ASL meet the demand for fast delivery of analytical results. Because shifts to new research areas can result in demands for more sophisticated analysis, development of those techniques will be needed.

Calls on RIL facilities and services are expected to remain at the present level or to increase. RIL must continue to provide laboratory space and facilities that comply with legal requirements and safety standards.

ASL will continue to render the following essential functions:

- Provide high-quality standard analyses of soil, plant, and water samples from IRRI's research programs and regional networks.
- Refine and standardize methods of analysis of soil, plant, and water samples.
- Establish high-quality, cost-effective, and rapid methods of analysis.
- Maintain and provide laboratory space and facilities for handling and analyzing radioisotope-labelled materials.

Shifts in program emphasis will affect the source of samples as well as the number of requests for analysis. Increased demand is expected to come from Germplasm Improvement (PA 100), because tolerance of rices to nutritional disorders is becoming an important breeding issue. Crop and Resource Management (PA 200) is expected to continue to be the major user of ASL services. Increased demand for ASL services will also result from the proposed program in Environmental Impact (PA 301). Collaboration is envisioned with Education and Communication (PA 400) in conducting on-the-job training. The need to reduce interlaboratory variation and to establish standard methods of analysis as the basis for objective evaluation of samples has been recognized.

Participation in an international sample exchange program designed to synthesize interlaboratory variations in analytical results is essential, indicating linkage to International Cooperation (PA 500).

Strategies

Projected activites. Use of ASL services is increasing. Samples from most experiments are analyzed for many elements to evaluate interrelationships. The body of information is building. As analytical data accumulate, they can be integrated to support development of an environmental characterization data base. Availability of chemical data from various geographic locations could obviate the need for additional analysis of certain locations of interest.

Centralization of facilities is cost-efficient. ASL has had experience in managing such a system in RIL. Laboratory space and facilities for similar special purposes can be maintained by ASL for use by research departments.

The analytical requirements of network projects involving collaborators with facilities for chemical analysis can be handled by those collaborators. Using common methods of analysis will minimize interlaboratory variability of results; that will be further improved by on-the-job training of collaborators. ASL is capable of conducting such training, if space and facilities are provided.

The following additional functions are deemed essential in the near future:

1. Establish a data retrieval system to support development of an environmental characterization data base.
2. Maintain and provide centralized laboratory space and facilities for special research purposes.
3. Provide on-the-job training for IRRI collaborators.

Space and personnel needs. The new research program strategy should recognize the role that ASL plays in the attainment of IRRI's research goals and should provide the logistic support for ASL to continue to provide high-quality analytical services. Calls on ASL have long since outgrown the rated capacities of its facilities. Long sample turnaround (2-3 months in the CAL) is a reflection of the difficulties of coping with current demands. Modern equipment and the data acquisition system now being designed are expected to reduce analysis time, but the real bottlenecks are sample preparation, digestion, and extraction, which are time- and space-consuming. Inadequate space can result in overcrowding, risking cross-contamination among samples, inefficient processing, and delays in completion of analyses. In addition, crowded chemical laboratories become health and safety hazards.

Additional laboratory space and personnel are required to improve the capacity of ASL.

604 Pesticide Residue Laboratory

Rationale. The Pesticide Residue Laboratory (PRL) was organized in 1977, extending from the pesticide residue analysis activities of the Entomology and Soil Microbiology Departments. It provides analytical services exclusively to IRRI scientists requiring pesticide residue determinations in their research. Consolidation of all pesticide residue analysis in one central laboratory under the supervision of competent chemists ensures reliable and comparable data and more efficient use and maintenance of the gas chromatographic facilities.

Organization. PRL, administratively attached to the Cereal Chemistry Department, has its own budget, facilities, and staff of chemists. An Advisory Committee with senior staff representatives from Agronomy, Entomology, and Soil Microbiology recommends guidelines and policies.

Principal activities. The role of PRL is to a) perform upon request analyses for pesticide residues in rice and other crops and in soil, water, and animals; b) develop, refine, and standardize procedures for pesticide analysis; c) provide expertise on analytical and chemical aspects, as needed, of IRRI research on pesticide formulations, applications, and environmental movements; and d) assist IRRI scientists in organic chemical analyses in which the PRL has expertise (e.g., gas chromatographic techniques).

In addition to PRL's own gas chromatograph units, units of the Cereal Chemistry Department are also assigned. A basic high performance liquid chromatograph is being purchased to complement the gas chromatographs for pesticide residue analysis.

Strategies. The new program structure is expected to cause little or no change in the type of samples and pesticides received from research departments for pesticide residue analysis.

Priority will continue to be given pesticide residue analysis related to IRRI scientists' research. The PRL special project in cooperation with the Irrigation and Water Management Department on monitoring pesticide levels in IRRI waterways will

have second priority. Nonresearch pesticide analysis and nonpesticide analysis of research samples will have low priority. Requests for chromatographic analysis of nonpesticide samples are anticipated to increase with the increased emphasis on basic research at IRRI; that may cause a bottleneck in PRL. A service for organic analyses could be established in ASL or as an extension of PRL.

PRL has two principal constraints:

Space. PRL works under a severe constraint of only 90 square meters of laboratory area. It does not have a pesticide formulation room for diluting formulations to residue levels for analysis. With the anticipated acquisition of more equipment (e.g., the high performance liquid chromatograph and extra storage freezers) an additional area of at least 50 m will be needed in the immediate future.

Quality control. To maintain reliable and accurate analyses, periodic upgrading of equipment and analytical techniques is required. A program that ensures periodic evaluation and critical review of PRL methodology by a short-term consultant pesticide chemist and upgrading of analytical knowledge and skills through outside training of staff are essential to maintain quality of output.

605 Seed Health Unit

Rationale. The success of modern rice improvement and production is attributed partly to extensive international collaboration on germplasm conservation, utilization, and exchange. With the increasing demand for gene sources to meet the varietal needs of diverse environments, the global exchange of rice germplasm and breeding materials will also increase. With this increased flow of seeds among rice-growing countries, the inevitable need is to maintain high levels of seed purity and seed health.

Organization. A seed unit was established at IRRI in 1981. In December 1982, an IRRI staff member was deputized as a plant quarantine officer with authority for rice by the Plant Quarantine Service of the Philippine Bureau of Plant Industry. The unit is now called the Seed Health Unit (SHU). SHU has its own budget, facilities, and staff. It is operated under the Technical Advisory Committee for Quarantine headed by the Head of the Plant Pathology Department, with members from Entomology, Weed Science, IRGC, IRTP, Plant Breeding, Cropping Systems, and Plant Pathology, plus a Deputy Director General. SHU staff perform crop health inspection, dry seed inspection, routine seed health testing, and seed treatment. There are three sections: Seed Processing, Quarantine, and Shipping.

Objectives. SHU works with the research departments concerned with maintaining IRRI's standards for seed purity and health, taking into account Philippine and other plant quarantine requirements to assure that quality seeds are exchanged.

Principal activities

Seed processing. The Seed Processing Section verifies that seed samples are of the variety claimed and ensures the purity of seed samples by removing germinated, discolored, misshapen, or broken grains; other plant parts; and seeds of other crop plants.

Quarantine. Quarantine certifies and phytosanitizes seeds received from or shipped to cooperating countries to meet the requirements of the Philippine Quarantine Service and those of importing countries.

Shipping. The Shipping Section assembles all phytosanitized certified seeds for packing, documentation, and shipping.

Strategies. In response to priorities set forth by different Program Areas relative to seed exchange, SHU will develop more efficient techniques to ensure that high quality seeds are shipped to and from IRRI, whether from domestic or international sources.

Such operations should also satisfy the needs of country programs, consistent with the quarantine requirements of the Philippines and those of recipient countries.

SHU will collaborate with concerned departments to:

1. Test the efficiency of published detection methods for seedborne pathogens and improve detection techniques and seed treatment for important pathogens.
2. Investigate the pathological bases of seed discoloration, physical quality, seasonal occurrence, and treatments necessary to reduce seed discoloration during seed production.
3. Investigate the relationship between diseases observed in field inspection and pathogens detected in laboratory seed health testing.
4. Assess the effect of important seedborne pathogens on seed quality during storage and germination.

5. Participate in international standardization or referee testing of detection techniques and seed treatment.
6. Provide training in rice seed health testing and treatment.

606 Environmental Data Service

Rationale. A quantitative understanding of land and climatic resources within each major rice environment is necessary in generating appropriate adaptable crop technology. Specific research goals and priorities must be defined and constantly evaluated in light of actual conditions in each rice environment.

IRRI's Germplasm Improvement (PA 100), Crop and Resource Management (PA 200), and Socioeconomic and Environmental Impact (PA 300) Programs require systematic information about the target areas in two main phases of research activities: a) research strategy design and b) technology evaluation, transfer, and impact. This is particularly important as IRRI accelerates research in rainfed rice environments, where strong germplasm-ecosystem interactions are observed. In rainfed lowland, upland, deep water, and tidal wetland rice, much better definitions of target areas and their critical constraints are required to fine-tune research priorities.

Target area analysis and evaluation are critical components at the technology testing and validation stage. Organized data on target areas help in achieving effective extrapolation in a cost-effective manner. Increased ability to extrapolate information to similar ecosystems will make network testing more useful and will increase confidence in networking among national programs and IRRI.

Organization. The proposed Environmental Data Service will replace the IRRI Climate Unit organized in 1978 within the Multiple Cropping Department to service Institute weather stations and to compile and analyze weather and climate data for all IRRI departments. Environmental Data Services, to be administratively attached to the Multiple Cropping Department, will have its own budget, facilities, and staff. An Advisory Committee of senior staff members will recommend policies and guidelines for operation.

Principal activities. The major activities of Environmental Data Services will be:

1. Compile, manage, and disseminate data on rice environments to support the development of a rice environmental data base.
2. Develop, refine, and standardize methods for interpreting rice environmental data.

Agroecological analysis requires five distinct types of data meteorological, edaphic, cropping system, biological stress, and socioeconomic each of which has distinctive attributes that require different handling in their collection, maintenance, and retrieval. A regional data base on the physical environment of rice-growing areas is being developed for South and Southeast Asia.

In terms of meteorological data, the unit services the weather stations at IRRI and at several IRRI research sites in the Philippines. It analyzes and publishes the data on a decade, monthly, and annual basis. Long-term climatic norms in the form of monthly mean data for hundreds of stations in South and Southeast Asia are collected, computer processed, stored, and archived as agroclimatic data banks for each country. Daily and weekly meteorological records collected for as many sites as possible in the rice-growing countries of Asia are used in selective studies of seasonal variation.

Edaphic data are obtained from available secondary sources. Currently these data are input at the scale of the FAO Soils map of the world. Data at larger scales are needed in the future. Spatial data on cropping systems and land use, on the occurrence and severity of such biological stresses as insects and diseases, and on mapable socioeconomic factors (e.g., rural population density, road density, farm size, and income) have not yet been included in the data base, although date is being assembled and methods refined to permit their inclusion in the near future.

Strategies. Priority will be given to developing an inte-grated environmental data base on the climatic, edaphic, and cropping system aspects of major rice-growing environments. The quality and quantity of data in the present data base must be improved, and additional parameters added. Data over a range of scales must be available for solving different problems, from the macro or regional (1:1,500,000) to the meso (1:50,000-250,000) and micro (1:100-1,000) levels.

More precise spatial location of ricelands is a major requirement for environmental analysis. Using remote sensing as a tool for riceland identification will be explored. Methods of building and using geographic data bases relevant to rice research will be established or adapted through contacts and collaboration with specialists at other institutions. A strong research linkage with PA 200,

in particular, will strengthen methodology development.

The international research networks (ARFSN, IRTP, and INSFFER) will require much more environmental data to analyze and interpret technology environment interactions. NARS also will need greater capabilities to characterize their own rice environments. Environmental Data Service will assist IRRI scientists to develop data sets and environmental analysis methods that will enable them to contribute in this area.

Visiting scientists and fellows will require methodology development support. Specialized training will be needed for some of the junior staff. Collaboration with other IARCs with experience in this area also will be sought.

607 Computer Center

Rationale. As IRRI's research activities expand, there is an ever-increasing need among scientists and administrators for efficient methods of data processing and information system management. The accuracy, versatility, and sheer speed of the computer make it an essential tool to support this need.

The IRRI Computer Center (CC) was set up in 1983 to centralize computer support for scientists and administrators at IRRI and their collaborators in the national programs.

Organization. The CC follows policies and guidelines recommended by the Computer Steering Committee (CSC), chaired by the Director General, supported by the Director of Administration, with membership of senior staff members representing computer users.

CC is comprised of three functional groups:

Computer Operations. Provides hardware appropriate to the central data processing needs of the Institute and efficient operation and maintenance of such equipment, its operating system, and utilities.

Technical Support. Operates and maintains the system and provides systems analysis and design, programming, and technical education. Effective information management requires efficient data storage and retrieval. Many software packages are available, but each needs to be modified and maintained. Although this group has developed many applications for user departments already, the advent of a sophisticated database management system and other new software will allow more users to develop their own applications and manage their own data, both on the mainframe and on microcomputers. Technical support personnel will spend more time educating users to develop and manage their own data processing applications, maintaining standards, identifying new and appropriate tools for client use, and managing central databases.

Management and Administration. Managing day-to-day activities of the Center, including personnel, budget, planning, and security. The primary function of management has been to provide and supervise technical support, not only for central computer facilities, but also for departmental computers. The demands for technical support have grown so that a large portion of management's time is being spent responding to ad hoc requests, to the detriment of some management functions. This problem is addressed in the section concerning objectives and strategies.

Principal activities. Because computers are located in CC and within each department, CC's major activities fall into two general categories:

Mainframe. The central mainframe computer facilities are primarily used for storage and analysis of research data. Software packages and compilers installed for this purpose include Statistical Analysis System (SAS) for statistics and econometric modeling and Fortran for scientific programming. IBM's Storage and Information Retrieval System (STAIRS) is used for bibliographic searches.

Demands for extra data storage facilities, increased computer processing power, and additional technical support are increasing. In 1985, major upgrades to the mainframe system provided a 1100% increase in main (CPU) storage and a 356% increase in disk storage. High speed tape drives were also installed, and extra technical staff were employed. Today, mainframe capacity is almost exhausted. In 1986, CC support for Administration and Budget & Accounting was added. Business language compilers (COBOL) have been installed. Increased Computer Center support is needed in these areas.

Microcomputers. There are 200 microcomputers of various brands distributed among departments. Microcomputer support has become the major service area.

As more computers are purchased, the user population also grows. This has created tremendous pressure for technical support in all facets of microcomputing, including purchasing, applications development, education, and hardware

maintenance and repairs. Frequently, support is requested only after purchases have been made by a department, creating unforeseen demand. The number of computers in NARS has also grown significantly, creating support demands outside IRRI.

CC has purchased eight microcomputers. The first was installed July 1986; the remaining seven will arrive in April 1987. These microcomputers are to be used mainly for testing and evaluating software, for systems development, and for computer education.

The consolidation and streamlining of IRRI's research programs and an integrated approach to research call for data storage and processing for scientific applications, information exchange, and management systems.

A communications network would be of major benefit to IRRI's research and administrative activities. Information sharing would be enhanced if IRRI's microcomputers could communicate with each other and with the mainframe. IRRI scientists also need to communicate with scientists in collaborating institutes, NARC's and IARC's.

Objectives. The overall goal of the Computer Center is to provide computer support for the ongoing activities of researchers and administrators of IRRI, and, where required, their collaborators in the NARS for data processing, communications, and information systems needs, and for computer education. Specific objectives are to:

1. Encourage the use of computers and information sciences as support tools.
2. Enhance computer expertise within the research and management areas, to promote end-user computing.
3. Develop improved communications methods for collaborative research and information exchange.
4. Stimulate the use of well-evaluated computer programs by testing, evaluating, and implementing suitable new or upgraded products.
5. Develop standards for data storage, data processing, and data security (database administration).
6. Develop the skills of Computer Center staff to provide expert computer support.
7. Develop and manage an ongoing computerization plan for the central computer systems of IRRI and the activities of CC.

Strategies. To achieve the above, CC will:

1. Computerization plan (5-10 year). Priorities and deadlines will be set, with new activities incorporated as the priorities and needs of the Institute change. Progress will be reviewed with management and users.
2. Education. Develop and support a continuous computer education plan for CC staff, researchers, and administrative personnel.
3. Communications Network. Expand the current mainframe computer terminal network and develop a Local Area Network (LAN) so that scientists' microcomputers may be linked to each other and to the mainframe system. This network could be expanded to allow connections outside IRRI.
4. Database Administration. Provide support for a data administrator in the design, operation, and maintenance of suitable database management softwares; guarantee standards and security of data storage and retrieval.
5. Technical support. Assist and support researchers and administrators in developing their particular applications by systems analysis, planning and design, plus advice and training on the use of new and improved development tools for systems development, office automation, data administration, etc.
6. Information System. Provide the management operations and technical expertise to support the total computer needs of IRRI by maintaining current awareness of trends and advances in the computer industry, so that new and appropriate tools of information science may be efficiently adopted. This will be achieved by collaboration with computer professionals and other computer centers or by using consultants for special projects.

608 Database Services

Rationale. IRRI's research is multidisciplinary, utilizing expertise from various fields of specialization to develop integrated solutions to major constraints to rice production in the world's rice-growing areas. For example, Germplasm Improvement (PA 100) integrates the efforts of breeders, who generate a large number of breeding materials, and problem-area scientists, who evaluate these materials under various biophysical and environmental stresses. Crop and Resource Management (PA 200) integrates research in crop

management, pest management, soil and water management, and socio-economics to identify the specific combination of environment and management that maximizes both yield and farm income.

Under such a research setup, solutions to problems are generally arrived at only after data from various areas of specialization, generated by several scientists in different departments, are integrated and jointly analyzed. For this reason, an interdepartment and interprogram database must be developed and managed for the whole Institute. This database should contain not only information contributed by IRRI scientists and their collaborators in national and international institutions, but also relevant information residing in existing databases in various parts of the world. Access to the database should be made readily available not only to all data contributors, but also to scientists in national programs.

Organization. The organizational setup for the Database Services will not be confined to a single research department or research services unit. While systems maintenance and database management are the responsibility of the Computer Center, system development will be handled by researchers in the various research departments who have the inclination and expertise. In order to streamline and coordinate the various activities and to avoid duplication and overlapping, a Working Group on Database, composed of key scientists from the different research program areas and research services, will be established.

Principal activities. The three major activities of the Database Services are described below.

System development. This involves system analysis and the design, testing, and implementation of a database system that will satisfy the needs of users, will be compatible with the types of information to be put in the system, and will be suited to the computer facilities of the Institute, national programs, and other participating institutions.

System maintenance. This involves routine and standard maintenance of existing database systems, such as monitoring of system performance and undertaking system modifications to solve emerging problems and to handle change requests.

Database management. This involves the day-to-day management of existing databases to facilitate user interaction for updating data and retrieving information. It also includes security and privacy controls and user authorization.

Strategies. Database work at IRRI started as early as 1975. Initially, work on databases was concentrated primarily in one department and was based totally on mainframe computers. It focused on the Genetic Evaluation and Utilization program. Substantial progress was made and a functional system was developed and installed.

With increasing expertise in computer use within the various IRRI departments, and with the increasing number of computers being managed by these departments, two major modifications will be introduced. First, the management of the database systems now in existence and of those to be developed will be decentralized. That is, management of departmental data will be handled primarily by the departments concerned. Only the integration of interdepartmental data will be the responsiblity of the central database management. Second, emphasis on developing new database systems will be shifted to PA 200 and 300, where very little such work has been done. We expect these systems to be more complicated and to involve more substantial collaboration with NARS, as well as with institutions in developed countries.

To implement the above strategy, the following activities will be undertaken:

1. Strengthen the capabilities of individual IRRI departments and IRRI collaborators in the computerized management of the research data that they generate and ensure the compatibility of computer data files created at the various sources.
2. Streamline data collection and management in the existing networks to facilitate the development of an integrated database management system.
3. Identify and evaluate existing databases in other institutions for their relevance to the needs of IRRI database users.

609 Statistical Services

Rationale. Statistics is a valuable tool for researchers to use in designing research, analyzing data, and drawing conclusions. For an IARC such as IRRI, it is essential that the best research techniques are employed in whatever type of research it undertakes, not only to maximize the benefit-cost ratio in research (i.e., to minimize the chance of experimental failure) but also to provide

a model for rice researchers in national programs.

To attain the level of excellence desired, researchers either have to be thoroughly familiar with the theory and application of statistics or be assisted by statisticians in designing their experiments and in analyzing and interpreting the results. Considering that most researchers are not trained statisticians, a Statistical Services Unit was established at IRRI at the beginning to provide the necessary statistical advice and assistance to all IRRI research staff, scholars, and trainees.

Organization. The Statistical Services Unit is an integral part of the Department of Statistics. The same staff who provide statistical services also conduct research on the development of statistical techniques and on the identification, adaptation, and modification of existing techniques to suit the specific requirements of rice experiments. This arrangement has greatly improved the capability of the staff to provide appropriate advice and effective services to IRRI researchers.

Principal activities. Two types of statistical services are provided by the Statistical Services Unit:

Consultation. Researchers and scholars can seek advice on all statistical matters related to their research planning experiments (choice of treatments, experimental design, layout, and data collection scheme); data management, analysis, and presentation; interpretation of results; and review of scientific papers.

Computing. Computational services are provided to perform statistical analyses (such as analysis of variance, mean comparison, regression and correlation analysis, chi-square tests, multivariate analy-ses, and genetic analyses). Computing services, however, are provided through staff consultation services, not directly to researchers.

Strategies. The Statistical Services Unit is designed to assure the use of correct and appropriate statistical techniques in all experimentation at IRRI. To meet this goal, the Unit must maintain an organization that allows it to respond to, and remain relevant with, the constantly changing research goals and thrusts of the Institute.

As IRRI's research programs give increasing attention to adverse environments, application of problem-focused research methods, and innovative research, the Department of Statistics will place increasing emphasis on the development of statistical techniques not only for research station trials, but, more importantly, for farming systems and on-farm trials; not only for irrigated, but also for rainfed lowland and upland conditions; not only for applied research, but also for more basic research. We plan to undertake these activities through close collaboration with, and direct participation in, the related research program areas. Through such involvement, the staff's capability to provide effective and relevant statistical advice is expected to be enhanced.

To provide the additional resources required for research and consultation, we plan to reduce our computational services by gradually strengthening the computational capabilities of the research departments through a) development of a micro-based statistical package (IRRISTAT) for direct use of IRRI researchers, and b) training programs in statistical computation for IRRI researchers. We expect this to be a viable strategy because of the rapidly-improving computer facilities at IRRI, especially with microcomputers now available in most research departments.

610 Information Services

Rationale. Although our primary means of disseminating the results of IRRI's research is through Scientific Publication (PA 402), IRRI scientists employ a variety of other channels to share their research with the worldwide scientific community. Among these are journal papers, conference papers, poster sessions, seminars, and internal and external reports. Information services in support of scientific programs include the production of about 130,000 slides/year, plus 42,000 black and white prints, 6,000 pieces of artwork, and in-house printing of about 18 million impressions.

In addition, all programs and departments, including IRRI administration, require a variety of communication support services in the pursuit of their missions.

Principal activities

1. Provide IRRI scientific staff with appropriate communication support in the dissemination of their research results to the worldwide scientific community.
2. Provide programs and departments with in-house technical support to enable them to meet their internal and external communication goals.
3. Provide IRRI administrative units with appropriate professional guidance in the development of communication materials and efficient, reliable technical services to produce them.

Strategies

General strategy. Develop and maintain well-equipped, professionally-staffed sections to meet the changing requirements of programmatic and administrative activities. These need to be predicated on the levels of growth incorporated into the Strategic Plan. They are tentative, in the sense that we do not know the directions of growth, but they are absolute, in that they will be required if programs expand. An example of a service that may be required is video production. Services required at various levels are: a) copyediting, b) photography, c) audiovisual, d) graphic arts and illustration, and e) in-plant printing.

Maintenance strategies. The maintenance strategies for PA 610 are:

1. Provide copyediting services to scientific staff and administration for journal articles, conference papers, administrative reports, lectures, brochures, programs, and instructional materials.
2. Provide photography services for scientific publications, record and ID pictures, and public awareness activities.
3. Provide audiovisual support (slides, audiovisual modules, posters) for seminars and scientific meetings, for production of instructional materials, and for exhibits.
4. Provide graphic design and illustrations for scientific publications, instructional materials, and the booklets, programs, and brochures required in public awareness activities.
5. Provide in-plant printing of all internal memos, reports, and standard forms, and support scientific publishing by printing conference preprints, the IRRI Research Paper Series, and scientific newsletters.

Growth strategy. Provide video newsclips for public awareness programs and video documentation for instructional materials, scientific experiments, and machinery demonstrations.

IX. Resource Allocation

To document change, it is necessary to quantify both how IRRI resources are currently allocated and the proposed allocation by program area and rice environment. The subjective time allocation of scientists to different activities was used as an approximate measure of this. It is recognized that the measure is imperfect, as the unit cost to support a scientist differs markedly among disciplines. Therefore, the resource allocation based on a per-scientist year and that based on budget allocation will not necessarily be the same.

Time allocation by program area

How IRRI's direct-hire headquarters and outreach senior scientists, senior scientists on long-term deputation from other IARCSs and organizations (such as CIRAD, ICIPE, IFDC, IFPRI, IITA, the Rockefeller Foundation, and the Japanese Ministry of Agriculture, Forestry, and Fisheries), and IRRI visiting scientists (VS) and postdoctoral scientists (PDS) consider that they now allocate their time, and their proposed time allocations to respond to priorities articulated in this Report, are summarized in Table 10. These figures include departmental estimates for senior staff now joining or being recruited. The scientists' perception of time allocation is subjective. It is also sometimes difficult (indeed, if not unreasonable) to allocate time among rice environments in those cases where research transcends environmental boundaries. Therefore, the analysis that follows should be regarded as indicative only.

The first point that emerges from the data presented in Table 10 is the substantial input to the Institute's research capacity provided by VS and PDS and by senior scientists from other research agencies with which IRRI has long-term cooperative agreements. Of the more than 100 scientist years now committed to research, VS and PDS account for nearly one third; senior scientists on secondment account for about 10% of the Institute's research capacity.

Staff on long-term assignment but not employed by IRRI significantly increase the Institute's total research capacity and provide specific expertise on a medium- to long-term basis. However, this strength may at the same time be a weakness; should these scientists be withdrawn, IRRI would have much less capacity in research areas considered central to its program. As a case in point, the recent reassignment of the IITA grain legume agronomist has reduced the Institute's capacity in varietal selection and management of legumes for rice-based cropping systems; those crops offer substantial

Table 10. Present and projected balance of IRRI scientific efforts in scientist years (SY) by research program area.

	IRRI senior staff[a]				Outreach staff[b]				Seconded/special projects[c]				VS & PDS[d]		Senior staff[e]	
	Current		Proposed		Current		Proposed		Current		Proposed		Current		Total	
	SY	%	SY	%	SY	%	SY	%	SY	%	SY	%	SY	%	Current	Proposed
I Germplasm improvement	14.0	25	14.1	25	1.6	18	1.7	18	3.8	38	3.9	39	9.5	27	19.3	19.6
II Crop and resource management	14.8	26	15.4	27	1.8	20	2.5	28	3.3	33	3.0	30	19.8	57	19.9	20.8
III Socio-economic and env impact	2.0	4	3.0	5	0.2	2	0.6	7	0.4	4	0.9	9	1.6	5	2.6	4.4
IV Education and communication	11.5	20	12.2	22	0.6	7	0.9	10	0.9	9	1.1	11	2.5	7	13.0	14.1
Scientific support[f]	2.6	5	2.6	5	0.0	0	0.0	0	0.1	1	0.0	0	0.7	2	2.7	2.6
Overhead	11.2	20	8.8	16	4.8	53	3.3	37	1.6	16	1.3	13	1.0	3	17.6	13.4
Current Total	56	100	56	100	9	100	9	100	10	100	10	100	35	100	75	75
Vacant positions[g]	8	–	8	–		–		–		–		–		–	8	8

[a]IRRI core and restricted-core funded staff. [b]Senior staff located in national programs, special-funded projects. [c]Senior staff on long-term assignment from CIRAD and ORSTOM, ICIPE, IFDC, IFPRI, MAFF Japan, RF. [d]Visiting scientists and post doctoral scientists, 1-2 yr appointment. [e]Senior staff: core staff, outreach staff, and seconded senior staff. [f]Farm, Computer Center, Statistical Services, and Database Management Services. [g]Vacant positions in Ag Econ, MCD (2), Engineering, Pit Breeding, Water Management, IRTP, IRGC.

opportunity for crop diversification, soil fertility improvement, and improvement in nutrition, income, and employment opportunities in Asian rice-based cropping systems.

The project-oriented selection of VS and PDS provides an opportunity to quickly and purposefully direct resources towards priority research areas. Planned shifts in the research portfolio emerging from this report may be achieved more rapidly by purposefully aligning selection criteria with IRRI's research plans, while continuing to be mindful of the needs of the national programs from which these scientists are drawn. However, from a longer-term viewpoint, IRRI must shift core resources to ensure continuity of focus and in-house capacity in priority research areas. This shift will be effected through:

- Time reallocation of current IRRI core staff.
- As vacant positions occur, hiring new staff with the necessary skills to provide capacity in priority research areas.
- Continuing to attract scientists from collaborating institutes to provide the Institute with specific expertise.

Currently, some 18 scientist years each are allocated to Germplasm Improvement and to Crop and Resource Management, supported by 1-2 scientist years of outreach staff time each, for a total resource allocation of about 20 scientists in each program. Fewer resources are allocated to Education and Communication (about 13 scientist years). Resources allocated to Socio-economic and Environmental Impact are quite small fewer than 3 scientist years. Scientific resources allocated to Research Support Services such as the Farm, Library, Computer Center, Statistical Services, and Database Services account for about 3 scientist years, in aggregate. More VS and PDS time is allocated to Crop and Resource Management than to Germplasm Improvement, with still smaller levels allocated to Education and Communication and to Socioeconomic and Environmental Impact.

IRRI senior staff located at headquarters consider that they allocate, on the average, about 20% of their time to administrative and other duties that cannot readily be allocated to research and training programs. Core staff located with national program and at other IARC's allocate considerably more time, on the average, to overhead (53%). Senior staff seconded to IRRI spend slightly less time on administrative duties (16%) than do direct-hire IRRI staff. Headquarters-located scientists believe it should be possible to spend less time on overhead, about 16% (i.e., a little over half a day/week), and consequently more time on research. Senior staff located in national programs would like to see administrative overhead reduced to less than 40% of their time allocation.

Respondents did not predict that shifts in scientific time among Program Areas would be necessary for IRRI to adjust to changing priorities. The main source of the increase in proposed staff allocation to research was envisaged to be the spending of less time on administration. Whether this is possible in a period when administrative responsibilities to support research programs seem to be expanding must be carefully assessed.

Allocation by rice environment

Table 11 shows how IRRI scientific staff consider their research activities relate to the five rice environments.

Scientists project that current research on the irrigated environment will fall, from about 25 to 22 scientist years. The most substantive shift between current and proposed time allocation within this environment is in Crop and Resource Management, which anticipates spending nearly 2 fewer scientist years on irrigated rice research and reallocating this primarily to rainfed lowland rice. Little change is projected in other Program Areas. Respondents believe that to permit IRRI to respond to its stated goals, research input to rainfed rice may increase from 11 to more than 14 scientist years. Research in rainfed rice is predicted to increase by about 3 scientist years, mainly in Crop and Resource Management.

Resources allocated to upland rice are also predicted to increase, by nearly 2 scientist years. Nearly a third of the scientist years of senior staff committed to varietal improvement for upland rice is derived from scientists on secondment from other institutes (e.g., CIRAD). Thus, with IRRI's current staff allocation, the maintenance of a vigorous rice breeding program targeted for this unfavorable rice environment is dependent partly on the decisions of other institutions to maintain resources at IRRI.

Resources allocated to the deep water environment will change little. This is not surprising, as IRRI has increased its activities in this environment by the appointment of a rice breeder and an agronomist in response to a recommendation in *A Plan for IRRI's Third Decade*, endorsed by the External Program Review of 1982.

Resources allocated to tidal wetlands and adverse

Table 11. Present and projected balance of IRRI scientific efforts in scientist years (SY) aimed at major rice-growing environments.

Item	Irrigated		Rainfed		Upland		Deepwater		Tidal/adv		TOT(UNASS)		Total	
	Now	Prop	Now	Prop	Now	Prop	Now	Prop	Now	Prop	Now	Prop	Now	Prop
A Senior IRRI core staff														
Germplasm improvement	6.3	5.4	3.0	3.3	2.0	2.4	1.0	1.2	1.6	1.6	0.2	0.2	14.0	14.1
Crop and resource mgt	7.2	5.5	3.8	5.0	2.4	2.6	0.8	1.0	0.6	1.1	0.1	0.3	14.8	15.4
Socio-econ and env impact	1.1	1.2	0.6	0.9	0.2	0.6	0.0	0.1	0.0	0.2	0.0	0.0	2.0	3.0
Education and communication	3.6	3.2	1.2	1.9	0.6	0.9	0.4	0.4	0.3	0.3	5.4	5.4	11.5	12.2
Total (n = 56)	18.2	15.3	8.6	11.1	5.2	6.5	2.2	2.7	2.4	3.2	5.7	5.8	42.2	44.6
B Seconded, special projects														
Germplasm improvement	1.8	1.8	0.2	0.2	1.2	1.1	0.2	0.2	0.4	0.5	0.0	0.0	3.8	3.9
Crop and resource mgt	2.3	2.0	0.3	0.3	0.1	0.2	0.1	0.1	0.0	0.0	0.5	0.5	3.3	3.0
Socio-econ and env impact	0.2	0.3	0.1	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.9
Education and communication	0.7	0.7	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.9	1.1
Total (n = 10)	4.9	4.8	0.6	0.8	1.4	1.6	0.3	0.3	0.5	0.5	0.8	0.8	8.4	8.8
C Outreach staff														
Germplasm improvement	1.2	1.0	0.2	0.2	0.1	0.1	0.1	0.2	0.0	0.1	0.0	0.2	1.6	1.7
Crop and resource mgt	0.3	0.4	1.0	1.1	0.2	0.3	0.2	0.3	0.1	0.1	0.0	0.3	1.8	2.5
Socio-econ and env impact	0.0	0.1	0.1	0.2	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.2	0.2	0.6
Education and communication	0.2	0.3	0.2	0.3	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.6	0.9
Total (n = 9)	1.7	1.8	1.5	1.8	0.4	0.4	0.6	0.8	0.1	0.2	0.0	0.7	4.2	5.6
D Total (A + B + C)														
Germplasm improvement	9.2	8.2	3.4	3.8	3.2	3.6	1.3	1.6	2.1	2.2	0.2	0.3	19.4	19.7
Crop and resource mgt	9.8	7.9	5.0	6.4	2.7	3.1	1.0	1.3	0.6	1.2	0.7	1.0	19.9	20.8
Socio-econ and env impact	1.3	1.5	0.8	1.3	0.3	0.7	0.1	0.3	0.0	0.2	0.1	0.4	2.6	4.4
Education and communication	4.5	4.2	1.5	2.3	0.7	1.1	0.5	0.5	0.3	0.4	5.5	5.6	13.0	14.1
Total (n = 75)	24.8	21.8	10.7	13.7	6.9	8.5	3.0	3.8	3.0	4.0	6.5	7.3	54.9	59.0
E Visiting and PD scientists														
Germplasm improvement	5.1		0.8		0.8		1.1		0.3		1.5		9.5	
Crop and resource mgt	9.9		4.8		4.6		0.1		0.0		0.5		19.8	
Socio-econ and env impact	0.6		0.9		0.2		0.0		0.0		0.0		1.6	
Education and communication	0.4		0.0		0.0		0.0		0.0		2.1		2.5	
Total (n = 35)	15.9		6.4		5.6		1.2		0.3		4.1		33.4	

Note: See Table 10 for definition of terms.

soils environments are projected to increase by about 1 scientist year. In response to recommendations in *A Plan for IRRI's Third Decade*, the Institute has appointed a rice breeder for this environment and has realigned resources in Crop and Resource Management to increase future capability.

In some areas, particularly in Training, Communication and Publications, and Statistics, it was difficult to apportion resources by rice environment. Unassigned time is summarized in the second-to-right column of Table 11.

IRRI's research is conducted by multidisciplinary teams drawn from research departments. Thus, the activities of scientists within departments may also be apportioned by rice environment and to overhead (Table 12). The largest department in terms of scientific staff is Plant Breeding, which proposes to allocate more than 3 scientist years to research in irrigated environments. Agronomy, the second largest scientific department, proposes to allocate similar levels of resources to irrigated and rainfed lowland environments (1.7 scientist years).

Allocation by Subprogram Area

Present and proposed allocations of IRRI scientific resources by Subprogram Area are summarized in Table 13. The striking feature here is that, with few exceptions, the scientist years per subprogram area are small – much less than 2. Indeed, the modal subprogram consists of 1-1.5 scientist years. Over three-fourths of the subprogram areas have 2.5 or fewer scientist years of research time allocated to them.

The largest proposed subprogram areas (those with 2.5 or more scientist years) are a) Disease Resistance and Breeding Methods (in Germplasm Improvement); b) Soil and Nutrient Management, Pest Management, and Rice Farming Systems (in Crop and Resource Management); and c) three of the four subprogram areas in Education and Communication. Alternatively, four proposed

Table 12. Proposed aggregate allocation of research by departments in scientist years (IRRI core staff, outreach staff, and senior staff on assignment and special projects)

Department	Environment					Unassigned and support services	Overhead	Total
	Irrigated	Rainfed	Upland	Deep water	Adverse			
Research Departments								
Agricultural Economics	1.4	1.7	0.9	0.3	0.2	0.0	0.6	5
Agricultural Engineering	0.1	0.3	0.3	0.0	0.0	1.0	0.5	2
Agronomy	1.7	1.7	1.1	0.7	0.1	0.0	0.8	6
Cereal Chemistry	0.6	0.2	0.1	0.1	0.0	0.0	0.1	1
Entomology	2.8	0.6	0.5	0.0	0.2	0.2	0.8	5
Irrigation Water Management	0.7	0.8	0.0	0.1	0.2	0.0	0.2	2
Multiple Cropping	0.0	0.5	0.3	0.0	0.0	0.0	0.1	1
Plant Breeding	3.4	1.1	1.7	1.2	1.7	0.0	0.9	10
Plant Pathology	2.2	1.1	0.9	0.2	0.0	0.1	0.5	5
Plant Physiology	1.9	0.1	0.2	0.2	0.1	0.0	0.5	3
Soils	0.9	0.7	0.4	0.0	0.6	0.0	0.5	3
Soil Microbiology	1.8	0.4	0.0	0.1	0.3	0.0	0.4	3
Statistics	0.0	0.0	0.0	0.0	0.0	0.5	0.1	1
Global Research Services								
CPD	0.0	0.0	0.0	0.0	0.0	3.1	0.9	4
IRTP	0.5	0.5	0.3	0.1	0.2	0.0	0.3	2
IRGC	0.2	0.1	0.6	0.0	0.0	0.0	0.1	1
RFSP	0.3	0.4	0.1	0.1	0.0	0.0	0.2	1
TTTD	0.8	0.5	0.2	0.0	0.0	0.0	0.5	2
Research Support Services								
Computer Center						1.0		1
Farm						1.0		1
Library						1.0		1
Database Management						0.2		0
Statistical Services						0.3		0
Others						0.1		0
Liaison/Outreach[a]	2.7	2.9	1.1	0.9	0.3	1.5	5.7	15
Total	22	14	9	4	4	10	13	75

[a]IRRI core funded liaison scientists and special funded cooperative programs. Note: See Table 10 for description of terms.

subprogram areas in Germplasm Improvement have less than one scientist year allocated to them: Grain Quality, Excess Water, Adverse Temperature, and Seed Technology.

The SPC will further examine the size of the proposed subprogram areas, in particular considering whether there are opportunities for functional aggregation, particularly in Germplasm Improvement. Because of the small sizes of subprogram areas, informal coordination possibly is desirable, and may be effective at that level. However, purposeful coordination among subprogram areas will be necessary to ensure that research within them is orchestrated to focus effectively on IRRI's priority research.

Shifts in resource allocation

Present and proposed time allocations by rice environment (as assessed by IRRI scientists) are summarized in aggregate in Table 14. The benefits anticipated from future research efforts in each environment, derived from Table 4, are listed in the righthand column. From the scientists' perceptions of their time allocations, it appears that somewhat more resource allocation has been and will be directed towards upland environments than corresponds to expected benefits. The Institute's lower and lessening investment in irrigated rice, compared with expected benefits, and its higher investment in upland rice, again compared with expected benefits, is consistent with IRRI's concern for equity and the comparative research capacity of national programs to deal with irrigated rice better than with more adverse rainfed environments. However, in recognition that irrigated rice will continue to be the main overall supplier of rice in Asia, the Institute does not believe that resources allocated to this environment should fall below 40% of its total scientific resources. The rainfed lowland rice environment is the second most important source of rice supplies in South and Southeast Asia, and its importance will increase if investment in irrigation stagnates. Thus, this environment is second in importance in IRRI's research portfolio

Table 13. Present and projected balance of IRRI scientific efforts in scientist years (SY) by research sub-program area.

	IRRI senior staff				Seconded/special project				VS & PDS		Total senior staff	
	Current		Proposed		Current		Proposed		Current		SY	
	SY	%	SY	%	SY	%	SY	%	SY	%	Current	Proposed
Rice Germplasm Improvement												
Genetic resources	0.8	6	0.8	6	0.9	25	0.6	14	1.4	15	1.8	1.4
Yield potential	0.9	7	0.8	6	0.3	8	0.5	12	0.1	1	1.2	1.3
Grain quality	0.8	6	0.7	5	0.0	0	0.1	3	0.3	3	0.8	0.8
Disease resistance	2.2	16	2.1	15	0.6	16	0.6	15	0.0	0	2.8	2.7
Insect resistance	0.8	6	0.8	6	0.3	8	0.2	5	0.5	5	1.1	1.0
Drought tolerance	0.9	7	0.9	7	0.1	3	0.2	5	0.0	0	1.0	1.1
Excess water	0.7	5	0.8	6	0.0	0	0.0	0	1.2	13	0.7	0.8
Adverse soils	0.8	6	0.6	4	0.6	16	0.5	13	0.4	4	1.4	1.1
Adverse temperature	0.2	1	0.2	1	0.0	0	0.0	0	0.0	0	0.2	0.2
Rice genetics	0.8	6	0.9	6	0.8	20	0.7	17	1.2	13	1.6	1.6
Breeding method	1.8	12	2.0	14	0.1	3	0.6	15	0.0	0	1.9	2.6
Seed technology	0.1	1	0.2	1	0.0	0	0.0	0	1.0	11	0.1	0.2
IRTP	1.7	12	1.6	11	0.1	1	0.1	1	0.4	4	1.8	1.6
Unassigned	1.4	10	1.6	11	0.0	0	0.0	0	3.0	31	1.4	1.6
Total	14.0	100	14.1	100	3.8	100	3.9	100	9.5	100	17.8	18.0
Crop and Resource Management												
Soil and nutrient management	4.0	27	3.4	22	1.7	51	1.6	54	6.3	32	5.6	5.0
Water management	1.7	12	1.7	11	0.r	2	0.0	0	1.1	6	1.8	1.7
Crop management	1.0	7	1.2	8	0.3	9	0.3	8	1.4	7	1.3	1.4
Pest management	4.7	32	4.9	32	0.3	9	0.3	10	3.4	17	5.0	5.2
Mechanization and post harvest	0.4	3	0.3	2	0.8	23	0.6	21	0.9	5	1.1	1.0
Rice farming systems	2.2	15	2.9	19	0.2	6	0.2	6	4.1	20	2.4	3.0
Unassigned	0.9	6	1.2	7	0.0	0	0.0	0	2.7	14	0.9	1.2
Total	14.8	100	15.4	100	3.3	100	3.0	100	19.8	100	18.0	18.3
Socio-economic and Environmental Impact												
Environmental	0.4	20	1.0	34	0.1	13	0.2	18	0.8	47	0.5	1.2
Production	1.0	49	1.0	33	0.2	58	0.5	53	0.7	44	1.2	1.4
Livelihood	0.6	31	0.8	27	0.1	30	0.3	29	0.2	9	0.7	1.1
Unassigned	0.0	0	0.2	7	0.0	0	0.0	0	0.0	0	0.0	0.2
Total	2.0	100	3.0	100	0.4	100	0.9	100	1.6	100	[illegible]	3.8
Education and Communication												
Non-degree training	2.8	24	2.8	23	0.4	39	0.5	43	0.5	21	3.1	3.3
Degree related training	2.0	17	2.4	20	0.5	56	0.5	48	0.2	6	2.5	2.9
Communication	5.7	50	5.9	49	0.05	6	0.1	10	0.0	0	5.8	6.0
Library and documentation	1.0	9	1.0	8	0.0	0	0.0	0	1.8	73	1.0	1.0
Total	11.5	100	12.2	100	0.9	100	1.1	100	2.5	100	12.4	13.2

Note: See Table 10 for definition of terms.

Table 14. Summary of current and projected balance of IRRI senior research staff efforts aimed at major rice growing environments, compared with anticipated economic returns from productivity increases in each area.

Environment	Current distribution[a] (%)	Projected distribution[a] (%)	Projected benefits[b] (%)
Irrigated	51	42	58
Rainfed shallow	22	26	27
Upland	14	16	4
Deep water + Tidal/adverse	12	15	10
Total	100	100	100

[a]Source: Table 11 figures adjusted to reflect percentage of time allocated to research activities.
[b]Source: Table 4

and represents the largest projected increase in resource allocation by rice environments.

When interpreting these data, it must be recognized that the estimates of rice yields in the different environments and of expected benefits are very approximate, and that the scientists' perceptions of their current and proposed time allocations are subjective judgments.

IX. Organization and Management

The section on research management will be developed following discussion with the Board of Trustees, being mindful of the recommendations of the recent External Management Review.

There is, however, a consensus among scientists that IRRI needs to establish a Research Council on the model of the Academic Council, with some external experts serving as members to monitor progress, suggest mid-course corrections in programs and priorities where appropriate, and screen and approve proposals for special projects. Such a Research Council should have the following standing committees to deal with specific ecologies and major fields of activity:

1. Irrigated and rainfed lowland
2. Upland
3. Deep water
4. Tidal wetlands and problem soils
5. Forward edge technologies
6. International collaboration

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Glossary

A

AARD = Agency for Agricultural Research and Development
ACIAR = Australian Center for International Agricultural Research
ADB = Asian Development Bank
AICRIP = All India Coordinated Rice Improvement Project
ARFSN = Asian Rice Farming Systems Network
ASL = Analytical Service Laboratories
AVRDC = Asian Vegetable Research and Development Center

B

BNF = biological nitrogen fixation
BPI = Bureau of Plant Industry (Philippines)
BRRI = Bangladesh Rice Research Institute

C

CAAMS = Chinese Academy of Agricultural Mechanization Sciences
CAAS = Chinese Academy of Agricultural Sciences
CABO = Centre for Agrobiological Research
CAI = computer-aided instruction
CAL = Chemical Analysis Laboratory
CC = Computer Center
CGIAR = Consultative Group on International Agricultural Research
CIAT = Centro Internacional de Agricultura Tropical
CIBC = Commonwealth Institute of Biological Control
CIDA = Canadian International Development Agency
CIMMYT = Centro Internacional de Mejoramiento de Maiz y Trigo
CIP = International Potato Center
CIRAD = Centre International de Recherche Agronomique pour le Developpement
CMI = computer-managed instruction
CNPAF = Centro Nacional de Pesquisa-Arroz, Feijão
CNRRI = China National Rice Research Institute
CPD = Communication and Publications Department
CRIFC = Central Research Institute for Food Crops
CSIRO = Commonwealth Scientific and Industrial Research Organization

E

EMBRAPA = Empresa Brasileira de Pesquisa Agropecuaria

F

FAO = Food and Agriculture Organization
FCC = Fertility Capability Classification
FCRI = Field Crops Research Institute (Thailand)
FOFIFA = National Center for Applied Research on Rural Development

G

GEU = Genetic Evaluation and Utilization
GIP = Germplasm Improvement Program
GTZ = German Agency for Technical Cooperation

I

IARC = International Agricultural Research Center
IBSNAT = International Benchmark Sites Network for Agrotechnology Transfer
IBSRAM = International Board for Soil Research and Management
ICAR = Indian Council of Agricultural Research
ICIPE = International Centre of Insect Physiology and Ecology
ICLARM = International Center for Living Aquatic Resources Management
ICRAF = International Council for Research in Agroforestry
IDRC = International Development Research Centre
IFDC = International Fertilizer Development Center
IFPRI = International Food Policy Research Institute

IIMI = International Irrigation Management Institute
IITA = International Institute of Tropical Agriculture
INSFFER = International Network on Soil Fertility and Fertilizer Evaluation for Rice
IPM = Integrated Pest Management
IRAT = Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres
IRGC = International Rice Germplasm Center
IRRI = International Rice Research Institute
IRTP = International Rice Testing Program

L

LAN = Local Area Network

M

MAF = Ministry of Agriculture and Food (Philippines)
MAFF = Ministry of Agriculture, Forestry, and Fisheries (Japan)
MSL = Mass Spectrometry Laboratory
MV = modern variety

N

NARS = National Agricultural Research Systems

O

ODA = Overseas Development Agency
ORD = Office of Rural Development (Korea)
ORSTOM = Office de la Recherche Scientifique et Technique Outre-Mer

P

PA = Program Area
PDS = Postdoctoral scientists
PEEM = Panel of Experts on Environmental Management for Vector Control
PhilRice = Philippine National Rice Research Institute
PRL = Pesticide Residue Laboratory

R

RIL = Radioisotope Laboratory
RFSP = Rice Farming Systems Network

S

SARIF = Sukarami Research Institute for Food Crops
SAS = Statistical Analysis System
SEARCA = Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SHU = Seed Health Unit
SPC = Strategic Planning Committee
STAIRS = Storage and Information Retrieval System
SY = scientist years

T

TAC = Technical Advisory Committee
TTTD = Training and Technology Transfer Department (IRRI)

U

UNEP = United Nations Environmental Programme
UPLB = University of the Philippines at Los Baños
USAID = United States International Agency for International Development

V

VS = visiting scientists

W

WARDA = West Africa Rice Development Association