Rice Research and Development Policy: A First Encounter

Proceedings of the research-policy dialog during the International Rice Research Conference

EDITED BY: R.S. ZEIGLER

IRRI

INTERNATIONAL RICE RESEARCH INSTITUTE

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Los Baños, Laguna, Philippines

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The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of 16 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization of the United Nation (FAO), the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). Its membership comprises donor countries, international and regional organizations, and private foundations.

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Contents

Foreword

Since the reorganization of IRRI's research program, the International Rice Research Conference (IRRC) has focused on ecosystem-specific issues. The 1995 IRRC, "Fragile Lives in Fragile Ecosystems", concentrated on the rainfed rice systems—the upland, rainfed lowland, and flood-prone ecosystems. In broad terms, the research goal in these ecosystems is to improve the well-being of rice farmers and consumers through sustainable improvements in agroecosystem productivity.

During the first three days of the conference (13-15 February), the 250 participants assessed progress in rice research and identified new research approaches for reducing constraints and improving productivity and sustainability of less favored and fragile rice producing areas. Papers presented on these issues are contained in a separate, companion publication, *Fragile Lives in Fragile Ecosystems.* Research, however, is only one of several approaches that must converge if significant impact is to be achieved for the diverse rainfed rice environments.

Ideally, research impacts should be compatible with the desired policy targets. However, because of competing social and economic demands, some policy targets may conflict with research outputs and create an environment hostile to the adoption of improved technologies. Organizers of the 1995 IRRC, therefore, added a new dimension of policy considerations to the traditional research perspective by setting up the first formal meeting of senior rice directors and policymakers from Asia during the last two days (16-17 February).

It was felt that a research conference focused on rainfed, less-favored ecosystems would be an ideal venue for a first exchange between policymakers and rice researchers. In these environments, many issues of critical importance to policymakers are particularly severe: rural poverty, population growth, gender inequities, malnourished children, poor infrastructure and social services, urban migration, and environmental degradation, to name a few. Here, issues of global proportions and consequences must be faced and solved.

In the past, the problems of complex and stressed rainfed environments coupled with extreme rural poverty dictated that few research resources were targeted to these environments because the probabilities of success were low. Now, however, with rapid growth of agricultural research technologies, new tools are available tor research, and these promise to bring a productivity revolution to the less-favored environments. But, are the policies in place that will permit investment in research where it may yield impressive gains? Are the proper institutions in place to foster the needed research, and is the scientific capacity in place or being developed? Are there means to make knowledge-intensive technologies available to farmers? Thus, our new IRRC dimension was to facilitate the interaction between policymakers and scientists. Specifically, the objectives were to

- sensitize researchers and policymakers to research-policy interaction and to identify pivotal interactions, and
- generate messages to policymakers and research directors as a first step towards an "action plan" to more tightly link research and policy in priority areas.

Find sessions of each of the various research issues discussed during the first three days were dedicated to summarizing the major research advances and identifying from a research perspective where policies may play a key role in enhancing or retarding the impact of research. To initiate the policy research dialog, prominent policymakers at the national and international levels were invited to present their views on the significance of agricultural research and its linkages to policy: Philippine President Fidel V. Ramos; Roberto Sebastian, then Philippine secretary of agriculture; Cielito Habito, secretary of socioeconomic planning and director general of the Philippine National Economic and Development Authority ; Dr. S. J. Das, Indian Ministry of Agriculture; Mr. Ismail Serageldin, World Bank vice president for environmentally-sustainable development and CGIAR chair; and then-IRRI Director General Klaus Lampe. Drs. M. Hossain and P. Pingali of IRRI, G.T. Castillo of the University of the Philippines Los Baños, and Dr. P. Crosson presented social science perspectives of policy-research Interaction.

The research-policy dialog was conducted as two one-haft day sessions in a roundtable format, with 30 policymakers and six research directors participating from 21 countries, primarily from Asia. The discussions were semi-structured, with issues developed from a mail questionnaire sent to the invitees and returned several weeks prior to the conference. Senior NARS Directors, K. Kainuma (Japan International Research Center for Agricultural Sciences) and M. Akbar (National Agriculture Research Centre, Pakistan) chaired the two sessions.

Introduction

ONE

Why do we need a research-policy dialog?

R.S. Zeigler

In most regions of the world people are better off today than they were in the 1950s, with the notable exception of sub-Saharan Africa. However, during the 1960s there were predictions of widespread famines and turmoil for the developing world over the coming decades, and especially for Asia. Countries such as India, Bangladesh, and Indonesia were seen as cases where little could be done to stave off disaster. These predictions were based on the premise that increases in food production could not possibly keep pace with rapidly growing populations. Fortunately, this premise has so far turned out to be false. Real prices of staple food grains have been steadily declining even as urban populations rapidly expand—the technology-driven growth of supply has continued to exceed demand.

The terrifying prospects of global catastrophe triggered by inadequate food supplies were more than simply gloomy predictions. They were real possibilities. A few visionaries realized the critical need for intensive efforts to reverse the trends in food supply in developing nations. Their efforts initiated the research thrusts that created the modern semidwarf cereal varieties and associated technologies. The widespread adoption of these technologies on favored, mostly irrigated lands, came to be known as the “Green Revolution”. The impact of this agricultural research-driven process has been remarkable in meeting the rapidly growing demand for food during the 20th century—especially in Asia. Over the last 30 years, for example, Asian rice production has nearly doubled , while populations have increased by only about 70%, resulting in a per capita increase of 18% in average rice consumption. Castillo (Chapter 5) provides a personal, first hand chronicle of rice-based agricultural development over the last 30 years,

In this complementary volume to *Fragile lives in fragile ecosystems,* we explore the food production challenges facing us as we move into the next century. A major focus is to begin to address policy and research interactions that may he needed to maintain the successes of the last 30 years, and to bring similar success to those areas that have yet to benefit from their own green revolution. In his opening address to the conference, Philippine President Fidel V. Ramos (Chapter 2), acutely aware of the critical link between economic growth and agricultural development, issues a call for a renewed national and international research effort to meet the food needs of the next century.

The interaction of policy and research: favorable environments

In most rice-growing countries, almost all irrigated ricelands are planted to modern rice cultivars, which account for around 70% of global production. Yet this impact did not result from research alone. The adoption and spread of modern rice technologies were a result of explicit and targeted policy interventions. These included investments in irrigation schemes and other infrastructure, development of modern agricultural research centers and universities, availability of affordable fertilizers and other agricultural chemicals through import policies and subsidies, and inexpensive and accessible credit. Without this favorable policy environment, it is unlikely that the spread of modern varieties would have been so rapid or so extensive. Without the prospect of a rapid and high return made possible by new varieties, it is unlikely that investments in irrigation, other infrastructure, fertilizer, and credit would have been nearly as attractive.

Government development policies are designed and implemented to achieve or maintain a desirable social or economic condition. These policy targets might be, for example, national food self reliance or self sufficiency, income and employment generation, equity across social strata, eliminating gender inequalities in education, and achieving certain environmental quality indices. Agricultural research, on the other hand, is generally designed and conducted to achieved some specific impact. This impact may he targeted as productivity increases, income increases, positive effects on the sustainability of the resource base, or decreased use of toxic agricultural chemicals, to name just a few. Thus, the outputs of agricultural research may serve as means to help achieve policy goals, and investment in agricultural research may be seen as a policy tool supporting these goals. In an ideal world, research objectives would directly support high-priority policy goals and policy tools would be developed to enhance the research process as well as the adoption and impact of research outputs. In this volume, CGIAR Chair Serageldin and Dr. Lampe (Chapters 3 and 4, respectively) address this interaction at the international research level. Sebastian, Habito, and Das (Chapters 9, 10, and 11, respectively) clearly illustrate the interplay between policy and research at the national level.

With the imperfect communication, diverse values, and often multiple and conflicting goals of the real world, the smooth interaction of research and policy is not as common as we would wish. Although policy intervention were major contributors to the success of green revolution technologies, they have sometimes led to unforeseen consequences as discussed by Dr. Hossain (Chapter 6).

Investments in infrastructure for favorable environments may not have been coupled with policies required for assuring the sustainability of the system and may have exacerbated regional and social inequities, that is, policies directed to the short-term objective of increasing technology adoption and productivity may have contrary effects over the long term if they are not monitored and adjusted. Policies on chemical inputs and irrigation subsidies offer two illustrations of negative policy-research interactions.

Artificially low and subsidized pesticide and nitrogenous fertilizer prices may have led to the misuse of agricultural chemicals. This misuse has contributed to disruption of the ecological balance in many ricefields where insecticide use is heavy. Beneficial organisms that normally keep pest populations under control are destroyed by the same chemicals intended for the pests, allowing the rapidly-multiplying pests to quickly develop damaging population levels. This leads to further applications, and ultimately to the "pesticide treadmill" where farmers must apply chemicals frequently yet still experience losses to pests. This ecological damage is compounded by the direct human health costs to farmers and their families and possible downstream costs as pesticide-contaminated floodwaters from sprayed fields flow into streams and canals.

Artificially cheap, or sometimes even free, irrigation water may contribute to intensive rice monoculture with two and three successive rice crops per year being the norm in some areas. Yields under uniform fertilizer inputs have been declining under such conditions and, in many cases, substantial increase in inputs have been required to maintain yields. Decline in total factor productivity appears to be a widespread phenomenon in intensive irrigated rice production system throughout Asia. There is mounting evidence that the reason for the decline is that continuous flooding of continuously cultivated irrigated ricefields causes changes in the soil chemistry affecting the soil's capacity to supply nutrients, especially nitrogen. Farmers respond to this by increasing their nitrogen fertilizer applications. Thus, water subsidies and inadequate management of irrigation systems may have led to system degradation, and cheap fertilizers may have contributed to masking early signs of this degradation. Excessive application of nitrogen fertilizers also can contaminate ground water with toxic nitrates. Subsidized fertilizers may also have led to replacement of more labor-intensive and complex soil nutrient management practices with inexpensive fertilizer (especially urea), adversely affecting soil organic matter and long-term nutrient soil supply and storage implications.

For the irrigated, modern rice variety-based systems, the initial interaction between policy and research was positive. Essential conditions for expression of the potential of the research output—adequate water and nitrogen and timely plant protection for initially vulnerable early varieties—were met by policy interventions. Then, research progressed in the development of pest-tolerant varieties and integrated pest management approaches that demanded far fewer and lower dosage pesticide applications, followed by the identification of yield decline concerns. However, with these advances, essential communication between researchers and policymakers has been less effective. Today, policymakers still see pests as the principal constraint to rice production and, as peri-urban irrigated areas are removed from rice, some from agricultural production altogether, public sector investment in irrigation systems is steadily declining.

The rainfed rice environments: awaiting research impact

While effective policy-research communication seems to be weakening in the favorable environments, the situation is worse for the less favorable, rainfed environments. Yields in rainfed ricelands typically range from 0.5 to 2 t/ha, and neither research nor policy interventions have made much progress in raising agricultural productivity. These rice ecosystems are faced with serious constraints to productivity increases. Drought is a common occurrence during the growing season in more than half the area; damaging floods occur in the rainfed environments as well. In some environments, flood and drought may plague the same ricefield in one year. Poor soils and intermittent pest attacks are also serious constraints in some areas. In most cases, the constraints interact and the overall severity and degree of interaction varies considerably from year to year.

Modern irrigated rice varieties were bred to perform well in an optimum environment, with crop management directed towards achieving as favorable an environment as possible. However, since water control in rainfed systems, by definition, is largely outside farmers' control and fertilizer responses are unreliable, it is not possible to create an optimum environment. Although modern varieties generally do not perform well, the modest efforts in rice varietal improvement for the very different rainfed areas have generally followed the irrigated rice breeding model—with predictably poor results. Faced with a variable environment, resource-poor farmers are reluctant to risk their very limited financial resources on inputs that may, if the year is poor, produce little return.

The heterogeneity and variability of the target environments and the difficulty of breeding for genetically complex tolerance to abiotic constraints have, so far, proved to be nearly insurmountable obstacles. Researchers simply have been unable to reliably measure, manipulate, and predict plant response to widely different environmental conditions. This, combined with the extreme poverty of the farmers in the rainfed environments, led researchers to conclude that a low probability of success warranted a correspondingly low research investment.

Inputs cannot be used for improving rice-based rainfed system productivity unless the plants are healthy and vigorous, can recover quickly from stresses, and therefore are able to respond to fertilizer application by producing higher yields. Similarly, natural soil fertility and fertilizers can be effective only if they are retained in the soil long enough tor the rice plant to absorb them. For both developing productive stress-tolerant rice plants and the means to manage the soil, the technological tools and knowledge base through the 1980s were inadequate to address the complexity facing rainfed environments. Improving rice cultivars for drought or submergence tolerance, for example. requires a sophisticated understanding of the physiology of tolerance, the genetic, governing the inheritance of the traits, and the manner in which the expression of the trait interacts with the environment. The genetics of stress tolerance tend to be complex, and only now have the breeding tools become available to efficiently manipulate the traits into high-yield backgrounds. Until very recently, the equipment required to precisely measure a plant's response to environmental stresses was large and unwieldy and could only be used in a laboratory context.

Not coincidentally, research stations were mostly located in favorable environments, which made research on unfavorable environment all the more difficult. Thus the critical interaction the crop and environmental factors has not been addressed. Crop management alternatives were hampered by the unpredictability of the effectiveness of inputs under different rainfall conditions. Thus most technological developed for rainfed environments were not suitable and resource-poor farmers could not be sure of a return on investment from their meager cash resources.

However, circumstances have changed. The revolution in microelectronics allows us to conduct experiments requiring highly sophisticated equipment directly in less favored environments far from mainstream research centers. Tools from the biotechnology revolution promise to allow us to understand, manipulate, and improve tolerance to our principal abiotic and biotic stresses. Controlled release polymer-coated fertilizes offer the possibility of efficient "on-demand" release of nutrients in periodically stressed environments. Computer simulation models linked to GIS, now possible because of the revolution in microcomputers and satellite imagery, allow predictive analysis of alternative technologies under a range of environmental conditions instead of repeating experiments over an almost infinite array of environments. Finally. investments in agricultural education by Asian countries have established adequate numbers of scientists to address problems of both the favored and unfavorable environments.

Hossain and Crosson (Chapters 6 and 7, respectively) deal with the complex issues of balance among investment options. They explore the issues surrounding investment choices from the perspectives of environmental impact and poverty alleviation. Pingali (Chapter 8) questions whether we should reconsider our research priorities in light of dramatic changes in the world economy likely to occur as GATT becomes a reality.

Emerging policy issues and questions

Within the changing research environment and as greater pressure is placed on the most favorable of the irrigated lands, a number of policy issues and questions need to be raised. For example:

- The evidence suggests that low agricultural productivity in rainfed environments is a cause of poverty, rather than poverty being the cause of low productivity. Assuming poverty alleviation is a policy goal, research towards increasing agricultural productivity would appear to be an attractive leverage point. But is it the most attractive?
- How should the prospect of growing water shortages in Asia affect investments in research for water-saving technologies?
- Reducing the rate of urbanization will depend on rural opportunities. What is the proper balance among investments to improve urban versus rural living standards and economic opportunity?
- What is the optimum balance between maximizing resource use and resource use efficiency with conservation of natural resources?
- Solutions to complex problems usually require correspondingly more sophisticated research. What is the proper balance between investment in advanced research and education facilities and opportunities for agricultural research versus research in other areas? Are the steps taken today adequate to assure the development of another generation of well skilled agricultural researchers?
- Second and third generation agricultural technologies tend to be more knowledge-intensive. What institutional changes may be required for assuring that farmers have the necessary skills and tool at their disposal?

A policy-research dialog

Research can now make meaningful contributions to productivity in rainfed rice environments. At IRRI in February 1995, the 22nd International Rice Research Conference reviewed research progress on a number of agricultural frontiers. A companion volume (*Fragile lives in fragile ecosystems*) extensively documents the research progress. However, a favorable policy environment will play a critical role in the eventual adoption and impact of new technologies. Our appreciation of this role prompted us to add a dimension to this conference to explicitly address policy needs from a research perspective. We sought the views of policymakers on investments for increasing agricultural productivity in less favored environments versus other investment options. Special attention was given to the issue of food security and self-sufficiency as the General Agreement on Tariffs and Trade (GATT) is being adopted by most rice-growing countries.

As already mentioned, this volume includes perspectives from prominent development and research policymakers at both the international and national levels. Social scientists present their perspectives on research balance under future scenarios, particularly in light of GATT. Finally, the results of the dialog between researchers and policymakers are summarized in chapters 12 and 13. First, we summarize those areas that researchers highlighted as most likely to offer significant near- and medium-term impact as well as the policies they see as needed to assure that impact is realized. Second, we present the views of two groups of policymakers invited to discuss their views of agricultural development in light of research progress and the changing social and economic environments facing them.

Notes

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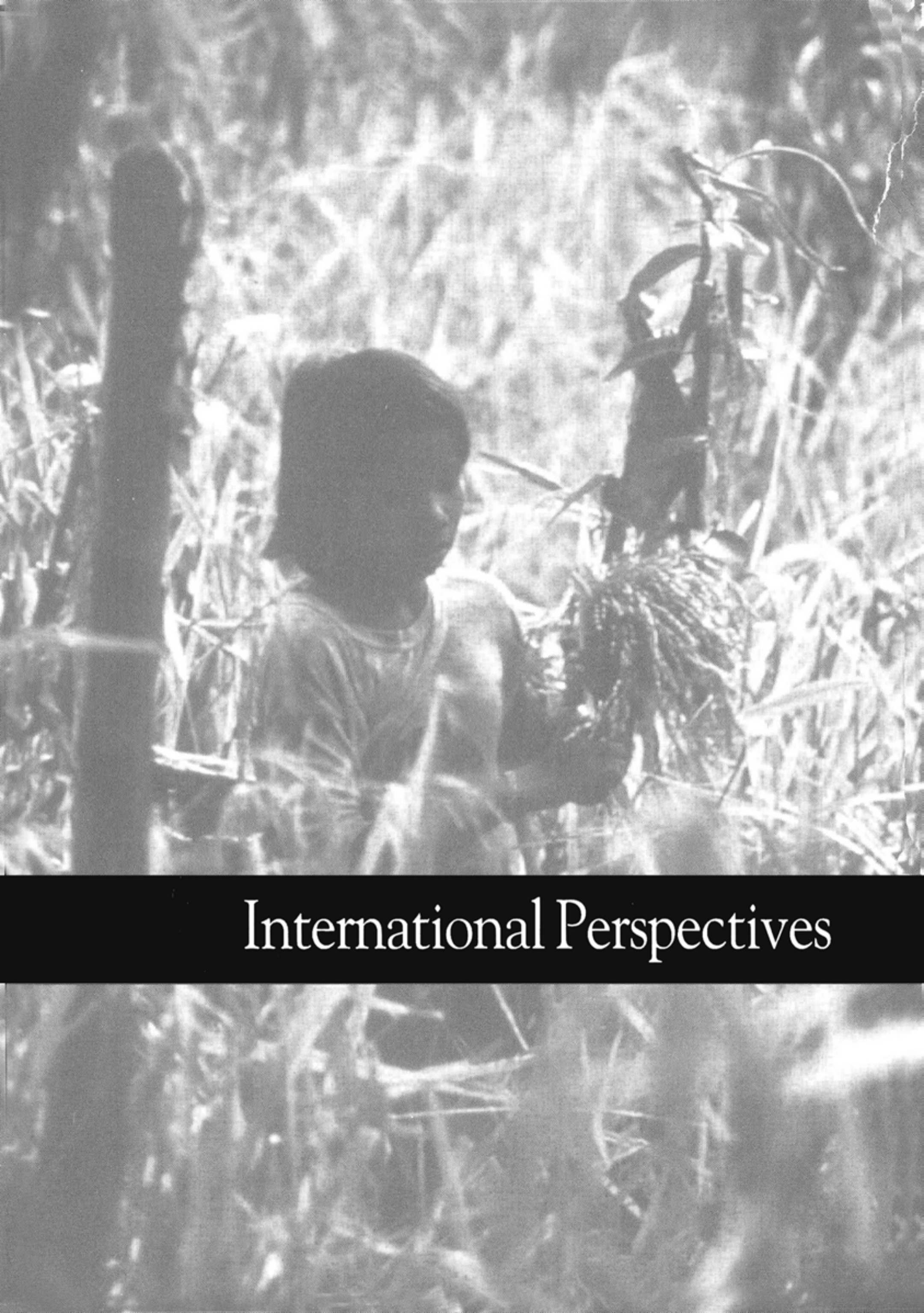
International Perspectives



Two

Needed: a second green revolution

H.E. President Fidel V. Ramos

It is the distinct honor of the Philippines to have been the host of International Rice Research Institute (IRRI) for 35 years. IRRI was founded by the Ford and Rockefeller Foundations in 1960 when the Doomsayers were predicting an impending world famine in the 1970s. The world, they said, simply would not be able to feed its growing population. All of you know very well that those predictions did not happen—mainly because the pessimists had underestimated the capacity of scientists to solve human problems. High-yielding, early-maturing, and fertilizer-responsive rice varieties produced by IRRI, and superior varieties of wheat produced by the International Maize and Wheat Improvement Center in Mexico, doubled and even tripled rice and wheat yields. Thus, the green revolution of the 1960s and 1970s was ushered in. The rest is history with which you are all familiar.

It is paradoxical that IRRI, although it has been operating in the Philippines for 35 years with privileges befitting that of an international organization granted by the Philippine Government, is not yet recognized as such in other countries. I, therefore, look forward to that in the near future when such broader international recognition will take place. We fully support the move to grant IRRI international status and are currently working on the executive agreement embodying this.

Benefits for the Philippines

The Philippines has greatly benefited from the research results and modern technologies produced by IRRI. For instance:

- Modern rice varieties and associated technologies, complemented by the governments investments in irrigation systems and support services, increased rice production in the Philippines at an annual rate of 4.2% from 1970 to 1989.
- The Philippine population increased from 39.2 million in 1974 to 65 million in 1994, while riceland decreased from 3.6 million to 3.3 million ha, yet our country has been able to achieve self-sufficiency in rice almost every year. This

was due to availability of modern varieties and associated technologies. In 1994, with favorable weather for rice production and a more focused government rice production program in Key Production Areas (KPA), we produced a record harvest of over 10 million t.

- Without modern rice varieties and associated technologies, the Philippines would have an annual rice deficit of at least 6 million t of rough rice, or 4 million t of milled rice. Importing that amount of rice at the current price of US$280/t would cost the country about US$1.1 billion.
- IRRI's collaboration with the Philippine Rice Research Institute (PHILRICE) and the Department of Agriculture in the promotion of nonchemical tactics for pest control through integrated pest management has resulted in the reduction of pesticide applications from 6 times in 1987, to 1 or 2 times per rice crop today. This has saved the country about US$15 million worth of pesticide importation every year, and has resulted in less pollution of the environment.

Declining donor support

Other countries in Asia have also benefited from the green revolution. Indonesia, a traditional importer of rice in the 1960s, 1970s, and early 1980s, is now self-sufficient in rice in spite of its rapidly growing population. Vietnam, using modern rice varieties from IRRI, is now exporting rice. India with its ever-increasing population, is also able to meet increasing demands for rice almost every year. Bangladesh, except for years of extremely bad weather, is able to produce more than enough rice to meet its needs.

Yet, support from the donor community for IRRI—and 15 other international agricultural research centers around the world under the Consultative Group on International Agricultural Research (CGIAR)—has been decreasing annually since 1989. Many donors have dropped food production and agriculture from their list of priorities, and now are putting more emphasis on environmental protection and natural resource management as priority areas for support, as if food production and environmental protection could be dissociated from each other.

Obviously, there is a need to reverse the trend of declining donor support for research on rice and other food crops. It is time that the developed and developing countries, particularly in Asia, which depend on rice as the principal source of calories, begin supporting rice at the national and international levels. Knowledgeable scientists, who appreciate the challenges of the 21st century better than most, have a responsibility to enlighten the donors—and the taxpayers, too. As distinguished and well informed scientists, effectively conveying to donors for agricultural research, this message of the need for greater support is essential to our survival in the future.

Second green revolution: a call for collaboration

We should guard against complacency on food security issues. Our immediate problem is how to increase rice production every year to meet the demands of 50 million more mouths to feed every year. Yet, there is almost no leeway to increase the amount of arable land tor rice production. Our biggest challenge, therefore, is how to produce more rice on less land—and how to do this with less water, less rural labor, and, especially, less of the pesticides that pollute our streams, rivers, and lakes. Obviously, we need another green revolution—a sustainable second green revolution that will meet the world's ever-increasing food requirements, and, at the same time, will protect our agricultural resource base and our environment.

The awesome, challenging task of producing more food with less resources cannot be accomplished without international cooperation. We need to harmonize the efforts of international agricultural research centers, such as IRRI and national research institutes and centers, such as PHILRICE, along with adequate support from both donors and the national governments. Equally important is the role of universities in research and the training of human resources, and the role ut the private sector in the use ot modern technologies in the production, processing, and marketing of food products and by-products.

National governments also have a key role to play in terms ot support services and appropriate government policies. I hope that you will include in your dialogue discussions on appropriate policies on

- international and national support for research and development;
- investing in rural infrastructure, such as irrigation systems, flood control, farm-to-market roads, and post-harvest facilities;
- investing in irrigated or favorable riceland versus investments in less favorable areas for rice production;
- intellectual property rights and seed production;
- commercial fertilizer and chemical pesticide issues;
- pricing policy that balances the interest of rice producers and consumers;
- achieving efficiency and effectiveness to be competitive under the GATT, without neglecting the needs of resource-poor farmers;
- removing policy biases against agriculture.

These are all important policy issues that need your full attention, and I urge you to comprehensively discuss these and come up with useful recommendations. I look forward to receiving a copy of your insightful views and recommendations.

In closing, I stress again the need for collaboration between international and national research centers, the need for continuing donor and national government support for research on rice and other food crops, and the need for concerted efforts of scientists, government policymakers and the private sectors. Without these, we cannot hope to have a sustainable second green revolution tor our food security in the next century.

And at the same time, let us bear in mind that your deliherations here will be only the beginning of a long process of new growth and production. The rice you produce will still have to be cooked, as it were, and served to the people. As one of our favorite sayings suggests:

> "Ang Bigas man, kahit na magaling, ay isasaing pa rin
> bago ipakain."

That is to say, "No matter how good the rice is, it still needs to be cooked to be eaten." Produce the rice, and we will do the rest.

Notes

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THREE

KEYNOTE ADDRESS:

Building robust livelihoods in fragile rice ecosystems: challenges and opportunities

I. Serageldin

Thank you very much Dr. Zeigler, Secretary Habito, Secretary Sebastian. Friends, it is an honor to be here with you today and I do mean that. It is a privilege to be at a seminar that tries to bridge gaps that have existed for too long, and tries to address issues that need to be addressed. By organizing this seminar, you have proved yourselves to be ahead of the consensus that was developed at the CGIAR Ministerial-Level Meeting in Lucerne. Secretary Sebastian was one of the prominent figures at that meeting, where a global consensus emerged for forging an international partnership on the problems of hunger.

The problems of hunger need to be approached at several different levels, such as global, regional, and national. We can argue, and correctly, that the world is moving closer to integration, as a result of technological change, than ever before. But at the same time, there are also problems of disintegration on the global scene. Let us look briefly globalization and homogenization.

The increasing interdependence of economies and the integration of financial markets are powerful forces of globalization. The financial markets of the word today buy and sell the equivalent of the United States Gross National Product in less than a week. And that is why there are forces out there that transcend the forces of nations. Those of you who remember the monetary crisis in Europe a few years ago will recall how that is the case. Second, there is another leap in environmental consciousness that is trying all together. As the old cliche reminds us, we are indeed all co-passengers on Spaceship Earth. What happens in one country affects another. Whether the problems of Chernobyl or the problems of global warming or the ozone layer, we are all tied in this together. And this begins to transcend national boundaries.

There is also an increasing awareness of human rights and democratic processes that have gained acceptance as universal values in every society today. And we see with it the rise of feminism, greater exertion of the rights of minorities and increasing recognition that processes are not what they used to be. Last but not least, I would, say, we have the emergence of a new international civil society. What happens to human beings or what happens to the environment in one country or another is increasingly of importance to members of the civil society across the globe. The impulses of the international civil society are strong, and its influence is far-reaching. These are all aspects of global integration.

At the other end of the scale, there are signs of disintegration, and they should not be ignored. These include the disengagement of the rich. This is an important point. The rich countries of the world are increasingly showing an inclination to disengage from world problems. They are turning inwards. They have their own problems to deal with and it is difficult to cope with both national and international matters, or so decision makers say. There is an increasing insecurity, as well. Even in the rich countries, there is an insecurity of tenure of jobs. Unemployment is high, exceeding 10-12% in Europe. In southern Europe, the percentage is in the high teens. There is an uncertainty about the future, and, when people are confronted with an uncertain future, they retreat into living for the present. And when the present is insecure, they move back into the past and try to latch on to a return to traditional values or a return to some aspect of past strengths, mythical or otherwise, that give them a sense of well-being.

There is an increasing fragmentation of decision making. In almost every country right now, decision making is less and less coherent and cohesive. We have single-issue groups that are influencing decision making everywhere in the world and increasingly so. But also because of communication and television and images, there is a wave of rising expectations. It has been said that the poor of Asia are remarkably patient. But there is a limit to that patience and I think that this is increasingly putting a new dimension into the problem: people see how the other half lives. No matter how remote you are, we are all linked into a global village. And most important, there are increasing inequities, both within countries and between countries. We talk a lot about inequities between countries. But within countries, both in the industrialized countries and in the developing countries, there is a rising tide of inequities. This is part of the transformation of economic processes toward an information-based society. The gaps between the information-rich industries — lawyers and computer programmers and what they earn—versus carpenters and welders are themselves increasing. But within each industry, the gap between the best and the worst, say, computer programmer, in terms of income is far larger than the gap between the best and worst carpenter or welder. There is a transformation that is taking place within society and between societies. And this is going to cause social strains and therefore something will have to be done to deal with these issues.

What we are talking about, therefore, is, in fact, people. We have to remember our common humanity. That against changing and broadening inequities that we see everywhere, we must reach out to those who are hungry, those who are marginalized. We must include the excluded; we must reach the unreached. And we must, in fact, as I used the term a year ago at IRRI, become the new abolitionists. A little over a century ago, people looked at slavery and said that it was unconscionable and unacceptable, that it degraded the free as well as the slave and that it was not a matter of improving the conditions of the slaves, it was a matter of abolishing slavery. In exactly the same spirit, I say to you that hunger in this world, today, is unconscionable and unacceptable. And that we collectively must become indeed the new abolitionists.

The good news is that development has worked. Life expectancy has increased by 20 years during the last 30 or 40 years. Infant mortality has decreased, school enrollment has doubled, people are better fed, people have access to safe water, endemic diseases have been controlled, and so on. It has been a track record of success and, therefore, there is no reason to claim that the issue of hunger is beyond resolution.

Agriculture was a key player in the success of development. The agriculture revolution was key in food production, in poverty reduction, and in environmental protection. Some environmental groups condemn the green revolution. They are wrong. For if you look, for example, at China, India, the U.S., and the Commonwealth of Independent States, they have all benefited from increased productivity. Both the availability of food and access to food have improved. While productivity increases have fed and nourished people, the new technologies protected the environment because less land was used to produce more food, thus sparing vast acreages from exploitation. Think of the environmental damage that would have occurred if we had kept the same average crop yields of 1960 and had to feed the population of today producing at the level we are producing today using more and more land. I have referred to the situation in China, India, the U.S., and the Commonwealth of Independent States. It is the same everywhere. The achievements have been remarkable. But much remains to be done.

In our world today, over 1 billion people live on less than US$1 a day. It you increase that figure to US$2 a day, you have three billion people. More than 1 billion people have no access to clean water. More than 1.7 billion people have no access to sanitation. These figures alone mean that we have 2-3 million eminently avoidable infant deaths every year. We have 1.3 billion people in the cities, mostly in the developing world, who are breathing the air that WHO says is unfit for human beings. We have about 700 million people, mostly women and children, who are suffering from indoor air pollution due to biomass-burning stoves, which is the equivalent to smoking three packs of cigarettes a day. We have hundreds of millions of poor farmers, who are unable to maintain the fertility of their soils. And these problems are aggravated by the addition of close to 90 million people a year to the world's population; more than the population of unified Germany. Some 95% of that growth is going to be in the developing countries. This means that food production will have to be doubled over the next generation, without further damaging the fragile environment. The challenge, therefore, is not to produce less as some environmental groups would like us to do but, in fact, to produce differently.

Let me move now, therefore, to the role of agriculture in addressing these global issues. This is a crucial question, for agriculture is the key to successfully addressing the environmental challenge, the poverty reduction challenge, the population growth challenge, and the food security challenge. It is the key because we saw that the growth of population is in the developing countries, which will accommodate 83% of the world's population by 2025. Almost two-thirds, of the world's population will be in Asia and the Pacific where rice is absolutely the prime staple. But the situation, the challenge, is the same in parts of Africa, in West Asia and North Africa, and in some parts of Latin America. A vast population has to be fed, and the greatest population increases will occur where poverty is most acute.

Consider the paradigm of the champagne glass, as defined and made famous by UNDP. What it says is that if you break the world population into quintiles, the richest quintiles, the richest 20%, receive about 83% of the world's income. The poorest 20% receive 1.4% of the world's income. Thirty years ago, the gap between the top 20 and the bottom 20 was 30 times, i.e., the top 20 was 30 times as rich. Now the top is 60 times as rich as the bottom 20. So the inequities are growing. And it is the people at the bottom who are the hungry, the malnourished, and the marginalized that are the primary objective of our work, whether it be on the policy side or on the research side, because ultimately they are the people we are trying to serve. They are packed into the whole bottom stem of the champagne glass. Look at the percentage of the poor that are found in rural areas. In some countries it is 91%, in others 86%, 79%, 67%, or around 50%. Poverty is still predominantly rural and if we are going to deal with poverty, therefore, increasing rural incomes—even in remote areas and low and fragile ecosystems or low-yield areas—is an essential part of poverty reduction.

In Lucerne, as Secretary Sebastian is aware, we asked ourselves whether there is a case for complacency about this food issue. Are we, people in the CGIAR and others, making a fuss about problems that do not exist. We noted that there are four views now prevailing in the world on food supplies. There is a complacent view, held by those who argue that markets will take care of everything. There is no problem, they believe: technology will happen by itself. That is an untenable view. Next comes the disaster scenario, in which there is no way of feeding these millions. So famine and hunger and starvation and civil strife are around the corner. The third approach is for the North to feed the South. Vast increases of productivity in the United States, Canada, and elsewhere will feed the South. And after a whole day of debates, participants in the Lucerne meeting found this approach to be totally unacceptable, and rejected it, because fundamentally it is disempowering. It does not reach the poor, and it will never be able to bring in those marginalized individuals of whom we speak. Fourth, there is what could be termed the CGIAR view, that disaster is a very real possibility, but can be avoided with a lot of work, doubling of resources for research, doubling of resources for strengthening NARSs, and appropriate policies. But it's not going to happen by itself, and this, therefore, calls us to confront head-on the many challenges we face, and of those challenges, a primary challenge is that of sustainably increasing the productivity of rice, which is the only agricultural option for hundreds of millions of human beings. It is not something that is just another tradable staple. It is part of life itself, permeating social and cultural traditions while being at the center of growth and prosperity.

I understand that IRRI is attempting to engineer the ideal rice plant. I commend your commitment and your efforts. But research has to link up with a second set of issues, which one would call the macro or national issues. We have heard, 1 think from Secretary Habito, a very clear statement of the perception of how the macro or national policy environment works. There has to be a consensus around the shared vision of what the country is all about and where we are going. Setting priorities is essential to mobilize all the social actors and create a framework encompassing the private sector, community groups, NGOs, farmers, and others so that they can all operate at their full potential. It is vital to consult, empower, and mobilize the poor when trying to meet the needs of the poor, because they are the ones who seldom have a voice in what we deal with.

Simply producing more is not enough, as we all know. In fact, we have heard Secretary Habito say that sustainable agriculture requires a lot more. It requires, among other things, a policy framework that recognizes that research is essential, but it is not sufficient. We need inputs, credits, markets, infrastructure extension, etc., etc. And, therefore, it is part of the coherent whole, and the policy makers are dealing with a lot of these issues of credits, markets, infrastructure. And this is where the dialogue between the scientists and the policymakers becomes extremely important, always keeping in mind, of course, that reaching the farmer, in order, in fact, to be able to reach the poor, is the prime objective.

Research remains essential, and research involves all of the actors I have mentioned. And they all need to be involved in a variety of intermediate steps before we get to either super rice or the perennial rice that, conceptually, holds out such promise. Research has to be directly linked with extension and the role ot the national research system, and here capacity building and education are central. The role of universities is fundamentally important, because universities are the crucible in which science operates and develops.

From there, we move to the micro. Why is it important that science be concerned with the micro policy environment? Because here we move, in fact, to the village and family level. Here we are reaching the unreached, and we must be concerned about their concerns. What we are concerned with is not just creating any technology anywhere, but creating the right technologies that will liberate the poor, increase incomes, develop a new and empowering system in which men and women can have charge of their own destinies, and take that first step upwards on the ladder of human dignity.

You are all committed to ensuring that your research is concentrated on the right problem, that you are producing the right technology, that you are involving the right actors, that you recognize the right scientific contribution is only one part of the solution. And, therefore, that dialogue that you have launched at this seminar is particularly important. But I seem to have addressed only one side of the equation, as if the policymakers and the conceptualists have a lot to give to the scientists, but not the other way around. And, I think, I have to redress that. Before I do so, let me just go back again to the theme of your seminar and conference. It is not just about increasing the production of rice. It is, in fact, partially about dealing with irrigation systems, but also about reaching out to those areas that are of low yield. Because if we don't reach out to those areas, we will not be able to reach the poor of today and tomorrow. And reaching out is really at the heart of what we are all about here. Thus, the commitment to work together with planners and policymakers, understanding the social and political context is important. What about the other way around? I believe that science has a lot to do with society, and that modernization and the development of society require the promotion of science; not as a means to an end, not as a producer of technology, but as a producer of values that are inherent in what we refer to as modernization and development, as distinct from Westernization.

When I speak this way about science, I am not talking about a particular piece of research, I am talking of science that is the organization of knowledge in such a way that it commands more of the hidden potential in nature—a beautiful definition by the late Jacob Bronowski. It is a very broad definition. It is more than a utilitarian application of knowledge. It impacts on our world outlook, as much on the perception of the self as on the perception of the world. A long time ago, people would say that what scientists do is too remote for most people. Only a few educated Europeans understood what Newton was talking about in his celestial mechanics. But gradually the idea that, in fact, there are laws that govern the natural world in which we live took hold. The fact that our relationship with that world is governed by laws, permeated our consciousness, permeated our understanding, and created values in which society changes, so it is an essential part of how we look at ourselves, society, and the world.

The knowledge that the exactness of science can give a context to our judgments is a powerful reason to rethink the need to promote science as an essential element in the development process. For we can all agree, I am sure, that the essence of development is humanism. That humanism is itself defined by a set of profound values that, in my mind, require the scientific outlook, and these are the values that nurture rationality, creativity, the search for truth, the adherence to codes of behavior, and what I might perhaps call, a certain constructive subversiveness. For, in fact, the enterprise of science is the constant undermining of the accepted and the known. It is to imagine that which was not and to try to prove it and by doing so, therefore, there is a subversiveness against the established authority inherent in the process of science but it is a constructive one because it carries us forward a step further every time.

What does it require, what do these science values of originality and protection of independence require? They require free inquiry, free thought, free speech, and tolerance based on respect, not on indifference. Tolerance derived from political liberalism, as distinct from the tolerance of science, can include indifference. You can say what you want, I really don't care, I will allow you to say it—that is the political tolerance of liberalism. But in science, when somebody challenges another thought, there is always a willingness to arbitrate the dispute based on evidence and certain rules of behavior. And therefore, there is a tolerance of different points of view that is very different from the tolerance of indifference. It is a tolerance that brings us together and that is why scientists form a network all over the world. They know each other by their writing, by their communications, even if they have never met before.

Scientists are not indifferent to each other's work; they cannot function if they are not part of the scientific community, a global community, increasingly so. And again, therefore, we have to look at what is happening in the world today. We talked about the population pattern. The vast majority of the poor, about 60%, are in low-income countries. Another 26% are in middle-income countries, so called, which are still within the stem of the champagne glass. Only 15% are in industrialized countries. The higher income developing countries are an insignificant 0.3% of the world's population. There is a huge gap that we have to face. Today, the number of scientists, just the number of scientists in the North as opposed to the South, based on UNESCO's figures, are more than 2,800 versus less than 200 per million. That enormous gap is a very big challenge and I am not talking about the quality of equipment that they have or the ability that they have to work with it.

In the future, will technology come to the rescue, or not? It may increase the gap or it may close it. In 1994, for the first time, more computers were sold than televisions in the United States—computers, of course, including hand-held computers, lap-tops, every kind of computer. It is an amazing new transformation. An equally important transformation is taking place before our eyes. The number of computers, the percentage of computers in the United States, that are hooked to a network, went up in five short years from 10 to 60%. The whole new transformation of the information age is upon us and the scientists of the developing world can, in fact, by virtue of that hook into networks of science in the North as well as the South, and can create networks and can facilitate creative partnerships.

Ladies and Gentlemen, what I have been trying to tell you here today is that this conference is indeed about reaching the poor and promoting rice production in low-yielding and fragile ecosystems. And it is motivated by the highest and most noble of ideals. But it is also about bringing together scientists and nonscientists, to share together a perspective, and with that we have a paradigm shift. Now paradigm shifts are not easy to bring about. But this new paradigm, a holistic view of science and society coming together, is a very serious one. And I know that many among the policymakers and within the society at large are afraid of it. But many of the scientists are also afraid of it because it is a step into the unknown. But let us remember, paradigm shifts, though hard, are essential. Therefore, we must work from here and elsewhere to strengthen that new holistic view that brings science and society together. Create that new paradigm not just for ourselves, but indeed for the poor and marginalized of the world, for the women who are suffering the inequities of the current status quo, for the future generations for whom we are custodians of this planet and, dare I say, for Mother Earth herself.

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Four

A fragile future in fragile environments

K.J. Lampe

The speed at which our world is changing is breathtaking. After centuries of stagnation in technological and social development, our generation has been bestowed with unparalleled technological, political, and social changes. Science, in most cases, has been the driving force of these developments. But contrary to earlier times, it has not been the lone scientist's innovations, but the outputs of multidisciplinary team efforts that have led to new plateaus of development.

The rural setting in which innovations of agricultural science are supposed to make an impact is adding another dimension. Young and fragile technologies must take root in a complex and sometimes harsh policy environment often dominated by persons far removed from the world of scientific experimentation and farmers' struggle for survival.

We all know it is uncommon for a scientific meeting, such as this international rice research conference, to culminate in a dialog with those responsible for policy decisions. However, this is part of our evolving research philosophy. We have come to the conclusion that agricultural science—including rice research—must encompass not only the social implications and consequences, but the political ones as well, related to the use of new knowledge and technologies that national and international institutions are developing. Scientists need an intensive dialog with farmers, the end-users of their outputs, at the planning phase of a research program. Researchers, who do not have a close relationship with those in charge of knowledge transformation and implementation, are in danger of developing useless products for a nonexistent market.

That is why we are extending our multidisciplinary dialog beyond the biological and social sciences—beyond research. Rice research outputs can only lead to impact if the political, economic, and social environments permit the use of new technologies, new tools, and new knowledge.

We must be prepared for more than 5 billion rice consumers in the next century. Feeding these people will require monumental increases in rice production. Doubling the yield from the present already high level in many countries may seem to be an impossible task. Some people claim that "the global house is already full", implying that the attempt to meet growing food needs is futile or, worse, counterproductive. We at IRRI have difficulties with such statements. First, we know that population growth will continue—despite all efforts—during our lifetimes and those of our children. Second, although some "rooms" in our global home may be crowded, we do not believe that the "house" is full. We know that, through changing the house rules, through better use of existing resources, and through the combination of new technologies and new knowledge, we can overcome the hunger of today and prevent growing hunger tomorrow. But, science cannot make the change alone, That is exactly why we have asked others to join us during the last days of this conference in our search for solutions.

This conference is honored by the participation of important partners in the efforts to meet the needs of tomorrow's children. Fidel V. Ramos, president of the Philippines, who is leading IRRI's host country through a remarkable transformation in preparation for the next century, indicated his commitment to agriculture by opening this conference. Roberto Sebastian, Philippine secretary of agriculture, and Cielito Habito, secretary of socioeconomic planning and director general of the Philippines' National Economic and Development Authority (NEDA), shared their views on the relationship between policies and research from a national perspective. We are also honored by the presence of a vice president representing the most powerful bank—the World Bank—responsible for economic development. Ismail Serageldin is personally in charge of environmental issues at the Bank and is chairman of the CGIAR, the leading world organization for international agricultural research.

The links between food and environment are very obvious for all those working in agriculture. For those on the outside, however, food and the environment are often seen as separate issues. This artificial dichotomy is at the root of a fundamental problem in development. Environment protection without fostering the interests of people living in those environments will result in transitory solutions, at best. If we ignore environmental issues in food production, we will literally "eat" the future of our children. Environment-friendly food production is the most successful means to protect ecosystems, especially the fragile ones.

But what is fragile and what is not? I am inclined to believe that given the present and expected human population on our planet, every ecosystem is fragile—endangered by unsustainable exploitation. Irrigated rice systems are often considered to represent the most sustainable production systems on earth. However, siltation of dams is occurring in a fraction of the time predicted during their planning stages. Water tables are rapidly dropping in many areas due to overuse of ground water. The most important, most productive rice-growing ecosystem—more than 80 million ha of irrigated rice that account for 70% of the global harvest—is now endangered as well. What will happen to the world if the irrigated ecosystem reverts to "rainfed lowland"?

It has become trendy to speak about farmers' knowledge, about grass root approaches, and about "community level" research. Let us not fool ourselves. If we have to harvest more than a billion tons of rice in the next century instead of 520 million tons today, we need new and sophisticated scientific knowledge—knowledge that the farmers of today cannot help very much to develop. However, when it comes to resource conservation and management, it is almost impossible to compete with the superior knowledge and experience of farmers, in all parts of the world. The irrigation system in Sri Lanka, intact for 1000 years, are a lesson in sustainability, as are the rice terraces of northern Luzon here in the Philippines. The cultures that built these systerns were based on continuity, on harmony with the environment, and on the willingness of people to sacrifice for the benefit of that continuity and not simply to maximize profits. What endangers fragile ecosystems today is the change in, and the erosion of, our values. We seem incapable of accepting old—some may even say outdated—values as a base for the future. We seem to be incapable of building new systems that can successfully compete with the traditional in terms of permanency and in the intelligent use of the natural resource base. Quick fixes and short-term success stories are not what we need.

Until recently, today's short-term profit perspective has placed little emphasis on ecological concerns. Modern planning and modern economics do not look too good if we compare the Mahaveli irrigation project in Sri Lanka, started in the 1960s, with the irrigation systems of King Maha Parakramabahu built in the 11th century. These are strong indications that today's project will not last a similar 1000 years. But, unsustainable development is not limited to today's societies. The lost cultures of the Mediterranean, the Mayas of Central America, the Incas of South America, and the Ur of Chaldea are dead monuments to human misbehavior towards nature. Losses of land, water, and human cultures were the prices paid. How often can we afford to repeat the mistakes of the past? Not very often. The limts arable land, the limits of water, and the linkage between water catchment areas, land use, and water availability all have been known for centuries—yet we do not use this accumulated knowledge. The consumption of nonrenewable sources is not only continuing, but accelerating, even with our growing knowledge of the devastating consequences to be expected.

Since World War II, we have divided many rural regions into two factions—the so-called "traditional" and "modern". Only now, 50 years later, do we begin to learn that what was called "modern" is not sustainable in many cases. It is time for a drastic rethinking, which must include the redefinition of agricultural economics. Some years ago, the World Bank made a start with an effort to include environmental factors in the equation of inputs and outputs. If the rate of return contains a "bad cheque" that will one day be presented to the next generation, the output will not only be negative, it will be unacceptable.

In the name of a free market society, we are in danger of irreversibly losing large areas of land. While short-term economic analyses indicate that it might be cheaper to import rice from elsewhere, they do not take into account that much agricultural land serves more than one single purpose. If, in monsoon-affected areas, agricultural land, specifically bunded ricefields, are taken out of production, they will not only be "put back to nature," they will only too often cease to function as environmental buffers that moderate soil erosion, store surface water, and replenish ground water. The results are not difficult to predict: floods, erosion, and dropping water tables. Should environmental degradation continue, enormous investment will be required to reverse the damage. Furthermore, at some point in the future, we will have to ask "from where will the rice come and how will the poor pay for imported rice?"

Our research community must be able to successfully answer the following questions: how are we serving the interests of the low-income society and are we contributing to long-term social, economic, and ecological peace?

The rainfed ecosystems we are focusing on during this conference are particularly vulnerable for many reasons—the overriding factors being people, population growth, resource use, and the rapid changes taking place today. Slash-and-burn is now a dirty phrase, but once it was a very useful, environment-friendly, stable system of agricultural production—until populations began to exceed the carrying capacity of that system. The rate of land turnover increased, shortening fallow periods from 50 to 5 years, turning what was sustainable into fragile. The irrigated systems face a similar problem. The 180 days used to produce a crop were reduced to as few as 110. The nutrient release capacity of soil has been stretched to beyond its present capacity. Not only must nutrients be released in a third less time, quantities must be supplied that support twice the yield. Our systems are now very clearly showing signs of stress.

That many of us believe our house is not full does not mean that we deny the urgency of controlling our population and our resource consumption. The pressure from growing populations puts pressure on the resource base that will translate into degradation if we do not act now and very fast. Here is where research must make its input. Fragile rice systems have to be stabilized as much as possible. Their productivity must be improved to meet at least the 30% of the increased production that must come from the nonirrigated systems.

You may rightly ask why we did not initiate a researcher-policymaker dialog earlier. There are many answers to that—but no excuses. First, we at IRRI had to be prepared for such a dialog. We had to restructure, reframe, and reorganize ourselves to meet the challenges of tomorrow. We needed a rethinking of our strategy and of our work plan that could lead to new policies, new approaches, new modes of operation, new structure, and a new role for the Institute. Entering into a policy-research dialog for the next century with a structure and outlook of the past would not produce the new thinking and collaboration we seek.

Having said this, I do not want to be misunderstood. What we are doing today would not be possible without the achievements already made, without the learning process of 35 years of international rice research. We must take advantage of the results accumulated and build upon them the research agenda for the future. Specifically, for the very diverse, nonirrigated ecosystems, IRRI's contribution can only be useful if closely linked through collaborative research with NARSs. We, at IRRI, as most of you know, are partners today in two formally established research consortia for the uplands and the rainfed lowlands. This arrangement of jointly planned, individually implemented, and shared research is, in my view, one of the lasting success stories of the recent history of the International Rice Research Institute. You may call it a shift from leadership to partnership or perhaps from independent research to a division of labor dictated by a jointly developed agenda. There is no doubt that cone sortia for flood-prone rice, and other ones must follow. IRRI will maintain its role as a research support institution, as a research center of last resort, as an institute dealing predominantly with problem solving, serving all consortia members. However, the diversity of ecological subsystems, local and subregional variations, brings national-systems to the forefront.

This has led to another shift in IRRI's mode of operation: more and more of our activities are demand-driven by strong voices from the NARSs. However, national systems that exist only on paper, that only take care of salaries—often not sufficient to attract the best—are not capable of serving the research needs of today. There is—to be very frank—one simple rule in assessing any agricultural research institution: If you need more than 60% of your research budget for salaries, you had better not expect any major output. How many national centers are in this circumstance? The answer is clear: quite a few. This raises another question: how much milk can you expect from a cow you do not feed? An economist might be able to produce with some travel cost, his or her brains, some paper, and a computer. Biological science, modern rice science by which we can expect breakthroughs in yield potential and permanency, is costly. We must confess that we have not done enough in the past to articulate the needs of national agricultural research. Yet, we do know that by such articulation through dialog with decision-makers, changes in perception, in priority setting, and in resource allocation can become a reality.

The ivory tower syndrome—the danger of narrowing down problem areas until we end up in subdisciplines around which fences are built—is not limited to agriculture, nor limited only to research. Only in very rare cases will it lead to practical solutions to real problems. We, therefore, must strive towadrs an open society in which listening to each other becomes a starting point for our intellectual contributions. We must realize that we can only expect support from those who allocate resources if we clearly articulate our needs, if we fully rationalize our research agenda, if we make sure that research fits into national long-term plans, and above all, if we are capable of demonstrating that our research outputs have impact on farmers' fields and serve our common goal:

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

Notes

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Policy Perspectives

FIVE

Rice, rice and beyond: understanding fragile lives in fragile lands

G.T. Castillo

On the occasion of IRRI's 10th Anniversary, I presented a paper entitled: *The New Rice Technology and Patterns of Rural Life in the Philippines* (Castillo 1972). It was an exciting subject to think about; inspiring to write; and easy to empirically substantiate. The green revolution was at its peak and so were the criticisms levelled against it. New rice technologies then were quite specific, well-defined, readily identifiable; and there were handy prescriptions on how to grow rice the modern scientific way, including calendar spraying. As rich a harvest as rice, was the harvest of literature on the socioeconomic consequences of the seed-fertilirer-pesticide-credit-irrigation-extension programs. Comparative studies of adoption-nonadoption of modern varieties in irrigated and in some rainfed areas quickly became passé because adoption was such an overwhelming phenomenon regardless of tenure status and farm size. Showing increased productivity and attributing impact to technology was relatively simple.

Looking back, socioeconomic research during those years included practically no diagnostic studies except for a few pessimistic prognostications about the likelihood of farmers adopting the so-called Cadillac varieties. Of course, it did not take long tor us to be proven wrong. Since adoption was taking place rapidly, social scientists focused their research attention on consequences ot adoption, hence their major role then was to monitor and assess impact. Diagnostic studies as input into the design of new rice technologies were not fashionable. After all, given a target of irrigated, favorable areas comparable to experiment-station conditions, scientists seemed to know the architecture, nature, and habit of the rice plant they needed to develop, went ahead and produced it. I don't think they consulted too many farmers about farming practices and varietal preferences. Scientists even succeeded in releasing good eating quality rice. These achievements convinced me that plant breeders were about as close to God as we could get. An inertia of euphoria went on for about 25 years and the contribution of science and technology tor the welfare of rice-eating and rice-growing communities was almost taken for granted.

Then came the observation of declining factor productivity in irrigated intensive rice production systems. Rice yields even in favorable environments seem to have "hit the ceiling" — a phenomenon labelled the "post-green revolution blues" (Cassman and Pingali 1995).

Such a chink in the armor of what was regarded as a stable and sustainable source of rice productivity introduces a new twist to policy implications for rice research. In a seven-country study regarding allocation of research resources for favorable and unfavorable areas, David and Otsuka (1994) concluded:

> Rice research has historically focused on favorable environments because of the higher probability of scientific success. The homogeneous nature of the irrigated areas also implies wide adaptability of new technologies, ensuring a high research pay-off. National and international rice research institutions, however, have been under pressure to shift research priorities toward the the unfavorable rice-production environments as a way to improve income distribution and alleviate poverty. Yet this multi-country study shows that factor and product-market ajustments largely counteract the potentially adverse effects of differential modern variety adoption across production environments.
>
> It is scientifically more difficult to develop new varieties, for unfavorable production environments are highly heterogeneous, so that superior varieties, even if successfully developed, can be diffused only in limited areas. Targeting rice research toward unfavorable rice-growing environments, therefore will not be an efficient means of improving income distribution. Furthermore, the potential gain in production efficiency in the rice economy as a whole is largely sacrificed under such a strategy, and that would have undesirable consequences on the welfare of poor rice consumers.

In the meantime, rice research in fragile lands such as rainfed lowland, upland, and flood-prone areas has been given unprecedented priority. Green revolution critics probably contributed to the shift in the current research agenda and donors supported the increased importance given to areas by-passed by the green revolution.

The theme of this conference—*Fragile Lives in Fragile Environments*—is an affirmation of the new priority accorded to fragility.

But nowadays, the demands on the talent and creativity of our scientists are going to be put not only to the test of productivity–enhancing technologies but also of sustainability, safety, biodiversity, social acceptability, ecological integrity, equitability and gender sensitivity. This is a pretty tall order indeed! It is for this reason that farmer-participatory approaches and interdisciplinary village and farm-level diagnostic analyses have been added to the researchers' tool kit.

Furthermore, we must take seriously IRRI's avowed goal and doubtless the goal of every national rice research system which states:

> To improve the well-being of present and future generations of rice farmers and copnsumers, particulary those with low incomes.

With this as raison d'ètre, we must understand how fragile lives in fragile environments survive. The state of their well-being lies at the heart of what rice research is all about. This paper explores the following "micro-scenarios" portrayed in many studies conducted in a variety of settings, which hopefully will provide social meaning to rice production in less than ideal conditions:

- Contra-indications to research concentration in irrigated system,
- Rice as a bridge of interdependence between rural and urban worlds,
- Livelihood systems and coping mechanisms in fragile lands,
- Seasonal calendar and rhythms of life,
- Land use and land tenure diversities in diverse ecosystems,
- Labor allocations and labor arrangements,
- Gender roles in rice farming system, and
- Sharing and managing rice genetic resources.

These eight micro-scenarios are meant to be illustrative of the social issues in fragile rice ecosystems. They are neither definitive nor even remotely comparative—they are simply a personal reflection of the state of the literature on the subject.

Contra-indications to research concentration in irrigated systems

The David-Otsuka policy prescription of concentrating rice research in favorable areas as a macro-rational argument for efficiency is fraught with a number of contra-indications. Not the least of these is the relatively recent recognition that even irrigated systems are not invincible, but are also susceptible to decline in productivity despite inputs.

The hoped for equalization through migration away from unfavorable areas likewise show signs of a reverse trend: Cruz et al (1992) estimate Philippines upland population increased at a rate of 2.3% per annum during 1980-90. Between 1980 and 1985 alone, a total of 2.5 million migrants are estimated to have left the lowland rural and urban areas for the uplands. De los Angeles (1994) finds evidence of considerable increase in agricultural cultivation of lands above 18% slope. Because the David-Otsuka study did not have village-level migration data, their conclusion with regard to the direction of migration from unfavorable to favorable areas is based on higher population growth rates and higher proportion of landless households in more favorable areas. But perhaps in many such places, the saturation point due to population pressure land fragmentation and declining productivity has been reached and therefore migration direction is not just rural-urban but lowland to upland and/or coastal. The latter continues to receive surplus labor, thereby resulting in population stress (de los Angeles 1994). For an illustration of the lowland doing damage to the upland, de los Angeles studied a group of erstwhile lowlanders cultivating a watershed area in Luzon. Over a short three-year period, yields went down from an average of 1.2 t/ha in 1978, to 0.6 t/ha in 1979 and only 0.4 in 1980. The lowlanders in search of land to cultivate brought their lowland cultivation practices to the upland thus creating rapid resources depletion (de los Angeles 1988).

Mascariñas recent study (Mascariñas 1993) of an irrigated rice village found 40% of households have members who have migrated mostly to Metro Manila. Cornesta et al (1986) found the majority of upland inhabitants in their research sites were migrants from lowland areas. Two general patterns of' migration are observed: l) the inflow of migrants not only from the lowlands but also from other upland areas to gain access to land; and 2) the out-migration of the younger sector of the population to seek employment.

A third contra-indication comes from sustainability concerns because unfavorable environments are natural settings for maintaining or enhancing biodiversity. What is the pay-off or ecological cost of low productivity and extensive expanding cultivation of biodiverse ecosystems?

David and Otsuka (1994) likewise argue that for the sake of distributive justice consistent with efficiency goals, investments in human capital (schooling) and in research on crops more suitable to unfavorable areas should be made. If technology for unfavorable rice areas is difficult to develop, other crops and better access to better schooling are not going to be easy either, even if as badly needed. At any rate, research on those "other crops" is already going. Unfavorable areas are usually even more unfavorable for crops other than rice. For example, rice is one of the few crops that tolerates submerged soil characteristics of rainfed lowland and flood-prone ecosystems. We cannot pass on the research task to another crop sector because unfavorable ecosystems are almost always multicrop and rice is one component. Rice research must contribute to the search for improved and more sustainable systems, where low productivity and deteriorating resource base are facts of life.

Finally, putting all rice research investments in one irrigated basket may not be the wisest policy, particularly where nonfarm sources of food security are not yet in evidence. This is a situation which still prevails in most rice-producing countries where poverty is also agricultural. In the Philippines, tor example, rice farming contributes 24% of poverty incidence in agriculture (Balisacan 1993).

Rice as a bridge of interdependence between rural and urban worlds

In international development fora, the discussions tend to center on urbanization and urban poverty as if agriculture has gone out of style. Among the rice-growing countries, except tor Brunei, Japan, North and South Korea, and Malaysia, the population is still rural and employment remains agriculturally dominated (Table 1). But rural-urban are no longer the separate worlds we defined them to he in the 1950s, 1960s, and 1970s. Rural-urban interactions are evident in such trends as: 1) farming affecting more families as a partial rather than as a main source of income; 2) even in typical rice-dependent villages, rice income is less than 50%; 3) the role of remittances in the life of the rural household has increased considerably. 4) migration to rural areas (particularly female migration) contributes to the rural household's income, part of which is invested in farming; and 5) improved food production benefits the urban poor through lower prices (Castillo 1994).

More specific to rice is Table 2 which shows the share of poverty groups in total populations and in national rice consumption. The trends are as follows:

- More rice is consumed by the urban than the rural sector but the urban nonpoor's share 32% is more than its share of the population which is 26.5%. On the other hand, the ultra poor's share of consumption is less (9.5%) than its share of the urban population (12.5%), probably reflecting the urban poor's lack of purchasing power.
- As in the urban situation, the rural nonpoor makes up only 17.5% of the population, but consumes 21% of the rice. On the other hand, the rural poor makes up 32.5% of the population, but accounts for only 26.7% of rice consumption; the ultra poor shows the largest gap between share of total population (20%) and rice consumption (14%).

Table 1. World population data sheet.

	Population mid-1994 (millions)	Percent natural increase	Percent <15 yr	Percent 65 yr+	Life expentancy		Percent urban
					male	female	
Bangladesh	116.6	2.4	44	3	54	53	14
Bhutan	0.8	2.3	39	4	50	48	13
India	911.6	1.9	36	4	57	57	26
Nepal	22.1	2.4	44	3	51	51	8
Pakistan	126.4	2.8	44	3	59	61	28
Sri Lanka	17.9	1.5	35	4	70	75	22
Brunei	0.3	2.6	36	3	69	73	58
Cambodia	10.3	2.9	44	3	47	50	13
Indonesia	199.7	1.6	37	4	58	62	31
Lao PDR	4.7	2.9	45	4	49	52	19
Malaysia	19.5	2.3	36	4	69	73	51
Myanmar	45.4	1.9	36	4	57	61	25
Philippines	68.7	2.4	39	4	63	66	44
Singapore	2.9	1.2	23	6	72	77	100
Thailand	59.4	1.4	29	5	67	72	23
Vietnam	73.1	2.3	36	5	63	67	21
China	1192.0	1.1	28	6	69	72	28
Japan	125	0.3	17	14	76	82	77
Korea, North	23.1	1.9	29	4	66	73	60
Korea, South	44.5	1.0	24	4	67	75	74
Mozambique	15.8	2.7	44	3	45	48	27
Tanzania	29.8	3.4	47	3	49	52	21
Madagascar	13.7	3.3	45	3	54	57	22

Source: Population References Bureau, Washington, D.C., USA.

Table 2. Share of poverty groups in total papulation and in national rice consumption (Philippines 1991).

	Population	Share of poverty groups in total population	Share of poverty groups in national rice consumption
Total Philippine population	63,135,953	Percent	Percent
Urban	31,619,220	(50.08)	(52.35)
Urban nonpoor	16,758,186	26.54	32.04
Urban poor	14,861,034	23.54	20.32
Ultra poor	7,904,805	12.52	9.48
Near ultra poor	3,794,306	6.01	5.41
Poor	3,161,922	5.01	5.43
Rural	31,516,732	(49.92)	(47.65)
Rural nonpoor	11,030,857	17.47	21.01
Rural poor	20,485,875	32.45	26.65
Ultra poor	12,606,693	19.97	13.98
Near ultra poor	4,412,342	6.99	7.22
Poor	3,466,840	5.49	5.45

Source: National Statistics Office, Family Income and Expenditures Survey 1991

While the rural sector grows rice tor the urban population; urban employment of rural migrants has its impact on rice farming systems, as shown in Padermchai and Shinawatra's (1992) study in Thailand. The authors found migration very high in the age group 16-30 years but higher among women (40-43%) than men (30%). The proportion of male migrants returning home (26.4%), however, is higher than for females (6%). While male migrants found such urban jobs in construction, factories, hotels, and restaurants, more than 50% of the female migrants find themselves in the entertainment business, often in sex trade. Since this job is better-paying, remittances from female-migrants are higher than from males. What is the impact of such out-migration?

"Migration causes labor-shortage, higher wage rates, adoption of mechanization but farm households enjoyed increases in income from remittances especially from female-migrants — even if they have lower education and less skills than the males." Their remittances are used to purchase farm equipment and other inputs (Paderchai and Shinawata 1992).

Livelihood systems and coping mechanisms in fragile lands

The pure rice farmer is a rarity whether in favorable or unfavorable area.. In Thailand, farm households earn as high as 67% of their cash income trom nonfarm sources, and in the northeast, the figure is 76% (Shinawatra and Pitackwong 1994). In other countries such as Nepal, Indonesia, Bangladesh, India, Philippines, Lao PDR, Cambodia, Myanmar, Vietnam, and China, depending upon their skills and access to nonfarm opportunities near urbanizing centers, farm households are engaged in diversified agriculture, off-farm labor, and different kinds of nonfarm activities including remittances from household members who have migrated to urban areas. Hence, it is more accurate to describe their food security and cash-income-generating strategies as livelihood systems rather than cropping systems or even farming systems.

One virtue in using the farm-household rather than the commodity or even the ecosystem pespective is that we begin to see the dynamics of diversified household strategies. It is not rice; it is not vegetables; its is not pulses; it is not fruits or forest trees; its is not livestock; it is not fish; it is not nonfood crops; it is not off-farm wage labor; its is not nonfarm work; it is not remittances, but combinations of the above, sometimes in miniscule amounts but in unimaginable permutation. It is not just adult men but equally women and children who participate in the production and decision-making process. It is not just field agriculture but also household gardens. It is also a fact that, in some places, even irrigated lowland rice-producing households are net purchasers of rice.

N.T. Castillo's review of coping mechanisms employed by landless agricultural workers (Castillo 1990) include the following:

- Participation in different kinds of work groups (i.e. prenda/gama/sagod arrangements wherein landless workers weed the fields tor free in exchange for harvesting rights or shares of the harvest; pakyaw/Kabesilyahan wherein flat rates are given for the performance of various farm operation; and work exchange groups for hire).
- Cooperation (whether intra- or inter-family) as a form of "shared poverty".
- Engaging in diversified income and livelihood sources (i.e. carpentry, gardening, livestock raising, vending, hiring oneself out as construction worker or domestic helper). These activities may also be viewed as means by which the landless leave the category of agricultural worker.
- Borrowing money or selling/mortgaging whatever little assets (including future labor) the worker has with relatives, friends, and usual sources of credit.
- Borrowing money to repay previous loans which leaves the landless worker in a state of perpetual indebtedness.
- Migrating to other places or seasonal mobility in search of job opportunities.
- Collective decision-making by the household or clan members regarding adoption of innovation or risk sharing.
- Prayers or resignation to one's fate.

Upland farmers generally employ a strategy that involves diversification of agricultural practices and diversification of income sources. These include the following:

- Niche shifting wherein the farm is extensively utilized during months of food abundance and during the months of food scarcity swiddeners shift to wage labor.
- Mixed cropping wherein subsistence/food crops and commercial/cash crops are combined on the same piece of land.
- Planting crops of different maturity periods to ensure that harvests are spread throughout the year.
- Changing the way agricultural products are disposed or used (e.g., consuming instead of selling most of the agricultural products during periods of food scarcity).
- Niche diversification, which is dependent upon the availability of resources.
- Raising livestock or growing vegetables in the home garden.
- Land sharing wherein upland households with no access to land are allowed to cultivate small portions of the land which their relatives are not currently using. This results in a shorter fallow period for the farm, and the uplanders who

have no access to land do this even though they are aware of the deleterious effects of such a practice.

- Practicing ecologically sound farming techniques or employing conservation methods in order to protect their resource base.
- Reliance on institutional support systems, such as nongovernmental organizations, credit facilities, etc.
- Scarcity adjustment or making do with less (i.e. having meals one or twice daily only instead of the usual three meals; tolerating low levels of nutrition and poor health; eating root crops if rice is scarce, etc.).
- Migration is the "ultimate strategy resorted to by upland farmers after exhausting all possible remedies in the village.

An intensive case study of socioeconomic relations within household food security in an upland village undergoing transition from subsistence to cash-crop farming (Keasberry and Rimmelswaan 1993) shows that: "their relations with relatives, friends and neighbors are involved with the exchange links of food, money, labor, land, and livestock."

The analysis indicates that "all social relations of the case households are really socioeconomic relations". The role of these relationships in the household food security of the families is manifested in the following ways experienced by different households:

- Households that regard socioeconomic relations as contributing only to a short-term solution for temporary seasonal food shortage.
- Households that think that socioeconomic relations do not make them more food secure since it enhances dependency on others.
- Households that consider their socioeconomic relations important to their household food security because they are inter-dependent with others or only more dependent on kinship relations.
- Households that regard the role of socioeconomic relations less important in their household food security because they are not dependent on them for their food supply.
- Households that think their relations are important to their food security are subsistence farmers who are experimenting with cash crops and the poorest cash-crop farmers, who still derive a part of their food needs from subsistence crop supplemented with some off-farm or nonfarm labor.
- Richest, cash-crop farmers consider their socioeconomic relations less important for their household food security because they can supply their food needs from the sale of crops and other more or less stable income sources.

- None of the households are food secure through exclusively cultivating subsistence crops or cash-crops. The families which are most food-secure are the really self-sufficient farmers who have the opportunity to cultivate rice.

The study of Mascariñas (1993) cited earlier provides interesting insights from rice-farming households that grow two crops of irrigated rice. Only a third of them reported adequate rice supply for the year, with inadequate rice supply for about 6 months. Farmers mentioned two environmental factors contributing to this food-gap: 1) occurrence of natural calamities such as typhoons, floods, and volcanic eruptions; and 2) lack of agricultural diversity. Irrigated lowland rice accounts for almost 99% of their agricultural land. The nature of their resource base restrains them from diversifying their rice-based cropping system. They also fear that this would further threaten their already precarious food supply. Thus, inability to take the risk of diversifying out of rice makes them more food insecure given their vulnerability to natural calamities.

Irrigated, rainfed, and upland farm households exhibit different socioeconomic characteristics, with upland households having lower education, lower income but higher proportion of land ownership. However, they have fewer opportunities for nonfarm employment because of limited education and skills and relative isolation from urbanizing centers. Tenancy and landlessness tend to be higher in irrigated, followed by rainfed areas (Luning 1976, Cornesta et al 1986).

In Pascual's study of upland and rainfed farm households (Pascual 1994), income from farming constitutes only about a third of their income. The rest came from agricultural wage labor, nonfarm labor; remittances, etc. (about 70%). It is also interesting that the smaller the farm size, the higher the proportion of off-farm and nonfarm sources. About a third of rice produced is sold although there are periods of food scarcity when households resort to substituting root crop for rice. More than 30% of maize, cassava, gabi, and bananas grown in the farm is consumed at home. Selling rice is attributed to the immediate cash needs for other consumption items. Quite often they end up buying rice for their use.

The composition of the rice farm households livelihood portfolio varies not only across ecosystems; but also across socioeconomic statuses; farm size; ethnic groups; proximity to industrializing or urbanizing centers; and the importance of rice in the local economy. For example, in three Cambodium provinces surveyed, 47% of rainfed households near Phnom Penh have nonfarm employment while only 21% for similar households in villages further away. Where the economy is based primarily on rice agriculture; few cash crops are raised and few source of alternative agricultural income are available other than tapping sugar palms to produce sugar (Lando and Mak 1994a).

For the purpose of identifying and defining problems and designing relevant technologies, this livelihood composition has to be elaborated in greater detail to explain variations.

Seasonal calendar and rhythms of life

Any diagnostic survey of fragile lands whether conducted for plant and soil science or socioeconomic reasons or both, wisely starts with the rice cropping calendar which details when different rice farm operations are done.

The calendar becomes more complicated when it expands into a cropping system or a farming system calendar. These seasonal calendars assume much social significance because all the activities are managed by the household. The content and sequence of events in the calendar determine the rhythms of life in a community and reflect opportunistic, creative, experimental, and experienced adjustment to rainfall; labor availability; subsistence needs; market demands; suitability to growing conditions; and interaction with other components of farming systems and nonfarm livelihood systems. In the case of shifting cultivation as practiced in northern Lao PDR, the rhythm of rice production is a multiyear cycle. Fujisaka (1994) describes the system as follows:

> With most commercial timber removed in northern Lao PDR, shifting cultivation is not an "integral" system. Shifting cultivation in Luang Prabang and Oudomsay was characterized by cutting, drying, and burning vegetation; largely rice monocropping; field fallowing; and rotation to other lands held by villages for the next cycle. Cropping intensity was greater in Luang Prabang where farmers generally cropped rice for two years and fallowed lands for three. Oudomsay farmers fallowed fields for an average of 6 years after cropping only once. Farmers in both areas slashed field vegetation in early February; burned and cleaned fields in March-April; seeded in May-June and harvested in October-November. Each farmer planted one to four upland rice cultivars; and up to 16 cultivars were encountered in each area. They grew multiple cultivars in order to stagger maturation dates and to, in turn, get an earlier rice for consumption, stagger demands for harvesting labor, and to stagger harvests so that timely harvests would reduce loss to wild animals.

Based on diagnostic surveys in five countries—south-central Cambodia; central and southern Lao PDR; northeastern Thailand; the Terai of Nepal; and Madagascar's middle west—Fujisaka (1994) has this general description of rainfed lowland rice systems:

> The rainfed lowland rice ecosystem is difficult and heterogeneous; and although its farmers are generally poor as a result, the shifting risks and uncertainties provided by the farmer and the corresponding adaptations developed by the latter probably illustrate farmer science at its best. Slight differences in elevation between fields result in different soil and water conditions; and therefore in farmer management strategies tailored to each plot. Rainfall, the key, varies each season—not necessarily so much in terms of absolute amount—but in terms of the timing of its onset and cessation, and in terms of periods of drought or flooding within. Rainfed lowland rice farmers survive by mastering the different calculus imposed by a tricky environment.

With respect to deepwater rice (DWR) in Cambodia, the seasonal flood is a principal factor determining the success of the DWR crop. The flood—the timing of accession, rate of rise, maximum depth and timing of recession—affects all Cambodian DWR farmers. DWR grows best where the flood rises no faster than 10 cm/day and has a gentle current (Lando and Mak 1994b).

In Madagascar, farmers practice longer-term crop rotations on upland fields. Fields are fallowed 1-5 years. Upland rice was sown in October-November, hand-weeded one to three times as necessary, and harvested in March-April. Maize harvest spanned early February (green maize) to late June for cobs "stored" on the stalks in the field (allowing farmers to complete lowland rice harvest, threshing, and harvesting of other upland corps). Farmers reported difficulty in obtaining sufficient labor for harvesting, transporting, and threshing. In the aggregate, farmers had different cultivars suited to upland; lowland rainfed and irrigated conditions, both short and long-duration cultivars, and both traditional and improved materials (Fujisaka 1990).

To understand household food security and well-being in different fragile ecosystems, a rice cropping calendar is not enough (Verdonk and Vrieswijk 1992). We need to put together information that would depict the following:

- Labor allocation calendar,
- Food consumption calendar,

- Illness calendar,
- Income calendar
- Expenditure calendar, and
- gender roles calendar.

When these calendars are superimposed on the basic cropping calender, we will discover periods of plenty and scarcity; peaks of labor; conflicting demands for labor and land use; time for earning and time tor borrowing; seasonality of malnutrition; time for selling and time for spending, etc. We might also discover that the period of food scarcity coincides with peak of labor demand and of frequent illness; that gender roles differ at different periods in the calendar such as when adult males engage in nonfarm wage labor elsewhere, women have to assume most of the farm activities that some households sell rice soon after harvest when the price is low and purchase rice before the next harvest when the price is high.

Land use and land tenure diversities in diverse ecosystems

In characterizing irrigated, rainfed, upland, and flood-prone ecosystems, each one is treated as a particular ecosystem ostensibly managed by four different group of farmers known as irrigated farmers, rainfed, upland or flood-prone farmers. But in real life, it is not unusual for farm households to manage more than one ecosystem.

Cambodia

The baseline survey of Lando and Mak (1991) in Cambodia provides one picturesque illustration of this phenomenon:

> Despite the prominence of the dry season crop in the area irrigated by the Srey Amphal system, the srok (District) is agriculturally diverse. Farmers have access not only to dry season rice land; but also rainfed lowland rice land; cash cropping fields on islands in the Mekong River; upland fields for rainfed maize and other cash crop production; household garden plots and occasional specialty agricultural fields such as reservoirs for lotus farming. Diverse kinds of cash cropping practiced provide substantial portion of the agricultural income of farm families in the District. Farmers cultivate fruit and betel for sale in their household gardens; rainy season maize, mungbeans, and vegetables in the upland fields; diverse vegetable cultivation on island fields in

the Mekong river and sugarcane and tobacco in fields between Route I and the bank of the Mekong River. Cattle, and to a lesser extent buffalo are abundant in the District. Only some farmers use cattle as draft animals because sale of calves is an important source of income.

Flood recession riceland tends to be dispersed and is granted yearly on a rotating basis. “Island field” is the most desirable cash cropping land (small but fertile garden crops). “Lake fields” and “upland fields” grow maize and vegetables. An individual rainfed lowland rice farmer may be managing fields which fall into: rainfed shallow—favorable; rainfed shallow—drought-prone; rainfed shallow—drought- and submergence-prone; rainfed shallow—submergence-prone; and rainfed medium deep—waterlogged. All these are within a single land allocation, which may not exceed 1-2 ha. Farmers in deep water rice had 30-40% of their lands in rainfed lowland rice.

Traditional rainfed lowland rice varieties are chosen to best suit field levels:

- Upper field—early maturing varieties that are drought-tolerant; subsistence rices with good volume expansion; these are harvested at the time when stock of stored rice is lowest.
- Medium field—late maturing varieties; good cooking quality and heavy grain weight.

The dispersed nature of individual land allocations over three different fields with a small size of 1.14 ha. and an average of seven different plots increases the problem of varietal management. The small farm size means farmers cannot grow sufficient rice for subsistence each year. As a matter of fact, 35% of households do not have sufficient rice.

The current system of land allocation originated from the Krom sammaki solidarity group, which was the collective agricultural production unit to which each farm belonged during 1982-89. By 1989, the influence of Kroms was on the wane and by the end of the year, they were defunct. However, this organization played a direct role in farmers’ land allocations and is still the focus for cooperative labor. Krom sammaki lands were allocated to each family from each field type—a proportionally equal share of each field type was received by all members of Krom sammaki. The intent was to avoid an unfair allotment of a large portion of the more fertile desirable middle or low fields to individual families. This organization has a profound effect on farmers’ differential access to the size and diversity of their land allocations as well as the nature of dry season agriculture in the system. They have allocations of irrigated dry season rice land, rainfed rice land, and garden crop land.

Nepal

Another very complex household organization in relation to farming systems under different environmental conditions is described in some detail by Bhuktan (1990).

The major fidings based on intensive studies of 18 rural communities from the central region of Nepal to represent different agroecological subzones are as follows:

- The two agroecozones are mountain (upper hills, intermediate and foothills) and Terai (inner and center). There are 10 different land topographies with more favorable areas as altitude decreases.
- Although all 204 households were land owners, half of the land they cultivated belonged to somebody else. They tilled other's land under legal tenancy, share-cropping and contract farming arrangements. Land constraint was more serious among mountain than Terai households. Usually a household engages in multiple tenurial arrangements as a risk-adjustment strategy. Land fragmentation was such that a hectare was made up of five parcels with average distance of 0.86 km. Farm households have to engage in multiple types of labor, power and water arrangements to avail of resources for crops grown in distantly located parcels. Crops have to he organized differently in the ecologically different land parcels.
- Socioeconomically, a debt-free, land-owning household was considered farming under favorable conditions. Almost all households were indebted in different degrees from multiple sources, with multiple credit arrangements and interest rates. Ninety percent of mountain households and 80% of Terai households were indebted and therefore farming under less favorable socioeconomic conditions.
- The average household grew 35 food and 31 nonfood crop belonging to 13 crop sectors organized temporally and spatially into 7 distinct cropping patterns in less than 1 ha of fragmented farm land. Food crops consist of grain staples, pulses, oil crops, vegetables, etc. Nonfood crops include fodder, fiber, fuel, fence building materials, medicine, narcotics, etc. All households grew some crop from all sectors, irrespective of ecological variations in their land All parts of the crop-plants are used in the household and every crop was multi-purpose. The food crops also served several other nonfood purposes.
- All Terai and 90% of mountain households grew rice as 13 spatio-temporal types in 28 intra-crop combinations. Two hundred four households grew 56 rice varieties (14 modern varieties or MVs and 42 local varieties) in 65 different varietal combinations. Two-thirds of the households had fitted MVs in half of their rice fields.

- The complex organization of diverse crops had resulted into 77 different cropping patterns. An average household had 7 cropping patterns. Diverse cropping pattern is not just due to bio-physical environment but also for sociocultural reasons. Numerous types of crops were pushed into the base crop as dictated by specific household needs. One of the important criteria that farmers used in selecting a crop was its capacity to accommodate other crops. Maturity period and sowing time were seriously considered to avoid any constraining effects on the preceding, succeeding, and/or simultaneous cropping. Different by-products were provided at different seasonal intervals.
- Each type of animal was kept for a specific use. Eleven types of animals were kept by 204 households organized into 30 different livestock patterns. Animals were reared for food, fertilizer, power, fuel, medium of exchange, means of repaying debt and collateral for credit.
- Since farm yard manure (FYM) is a highly valued source of nutrient for crop farming, households had to organize livestock farming in relation to crop farming. FYM is applied annually but Terai had greater use for fuel, hence FYM was applied only in alternate years.
- Most households acquired water for irrigation from private property, common property, and government property arrangements.

India

In India, Grewal and Johl (1991) report that most of the rainfed states have higher proportion of scheduled castes and scheduled tribes engaged in farming and the proportion of small and marginal operations is also high. They also had lower literacy levels and higher proportions of female labor input in farm operations, 17% in Punjab while rainfed states like Madhya Pradesh and Kerala where it was 42 and 64%, respectively, for paddy crop. Gupta (1991) has also said that in a rainfed economy it is not the crop but the livestock which is the main anchor of the household survival system in dry regions. Within livestock, the small ruminant, i.e. sheep and goats, are owned by more vulnerable groups compared with the rest. Once this is recognized the primacy of fodder, whether from grasslands, trees, or crop residues, vis-a-vis grain becomes clear. As has been described earlier for Nepal, Gupta (1991) notes:

> ... different social classes of rural households have chosen different combinations of crop, livestock, tree and other enterprises in different ecological regions. The historical experience, accumulated debts/deficits or surplus in the household budgets, technology, successive or alternate losses

or gains besides future expectations are some of the major factors which affect household perception of high risk environment, access to factor and product markets, kinship networks, intra- and inter-household risk adjustment options, public and common property survival systems help in defining micro limits of the niches of technological suitability.

Philippines

Shifting cultivation in the uplands in countries like the Philippines seem to have reached a point of "no return" or "little return" with declining levels of crop production and soil degradation. Campilan (1994) describes the situation as one of shorter fallow period; shorter cultivation cycle; smaller farm size; limited cropping system with a shitt from planting cereals to root crops; increased erosion; cogon infestation and insufficient labor supply. Toward a more socially tolerant environment for the short fallow system, some people decide to cultivate farms in the more remote upland areas which have been left generally idle. Although this is more laborious, the practice avoids social conflict by not directly competing with others for available land.

Security of land tenure has always been assumed to have an impact on adoption of sustainable agricultural practices. The evidences are still scanty and the coditions under which this relationship holds are rather ambiguous. At any rate, upland farmers also exhibit various tenurial arrangements such as: claimant cultivators in public lands; owner-cultivators in private lands; tenants in both public and private lands; and farmers with mixed tenures. The latter cultivate several parcels of land under varied tenure systems (Cornesta et al 1986). What is worth noting is the tendency of farmers who have both upland and lowland parcels to dispose of the upland parcels in case of dire need such as illness, etc. Clearly, the lowland is of higher value to the farm household.

The connection between tenure, security, and adoption of difterent crop management practices in the uplands is important not only for the upland households themselves, but also for the continuing productivity of the lowland. But the interactions between the biophysical and the socioeconomic variables need to be better understood.

In summary, people in unfavorable ecosystems also live under unfavorable socioeconomic conditions including increasingly limited access to land. These areas can be characterized as DCR in Chambers' terminology (cited in Campilan 1994): diverse environments, complex farming systems, and risk-prone production conditions. To these, we add varied labor and land tenure systems, ranging from the egalitarian intentions of countries that have just decollectivized to less flavorable sharing arrangements under tenancy, decreasing farm size, land fragmentation but increasing land consolidation in others, and higher incidence of the truly landless. Unlike in the past, the present agricultural landless are those who have no access to land to cultivate, let alone own.

Labor allocations and labor arrangements

From the review of farm and village-level diagnostic studies in unfavorable ecosystems in Lao PDR, Cambodia, Nepal, Philippines, Thailand, Vietnam, Madagascar, and India, labor shortage is commonly cited as a constraint in farm activities and as a deterrent to adoption of labor-intensive crop management practices such as green manuring, economic threshold levels for IPM, weeding, nutrient management, etc. Because of this labor constraint, the diagnostic studies suggest that very careful attention be given to labor requirements in the design and development of more productive technologies. Quite often low-input technologies means high-labor expenditures. But the real puzzle lies in the phenomenon of people plenty but labor short. At the macro level, these countries are still characterized by relatively high rates of population growth and/or large populations.

There are several likely explanations for this puzzling phenomenon: complex and labor-demanding but low-yielding production systems; competition from off-farm jobs and nonfarm livelihood opportunities; low energy levels of farming households; limited availability of nonhuman power sources; unattractiveness of farming particularly to the young; rural-urban migration; lack of labor-saving but knowledge intensive practices; high proportion of young school-age population who are deliberately being educated out of farming, and shifting labor arrangements from cooperative/exchange toward hired labor paid in cash.

For a glimpse of what is happening to labor arrangements, we present the following as illustrations.

In northern Lao PDR where shifting cultivation is still practiced, Fujisaka (1994) reports that cooperative work groups decide which lands shift from being cultivated to fallow for the next season's cultivation. Cambodia probably exhibits more varied arrangements than other countries. For rainfed lowland rice, the primary source of labor outside the household is exchange labor despite the difficulty of scheduling labor exchanges for rainfed cropping operations. Households that exchange labor did so primarily with former members of their Krom sammaki. Plowing is done individually or cooperatively. Weeding is exclusively family labor. Transplanting makes the greatest use of cooperative labor. Threshing is family and cooperative labor and although harvesting is cooperative, labor scheduling is difficult hence family labor is resorted to for varieties of different maturities (Lando and Mak 1994a).

Exchange labor is important in deepwater rice but hiring labor for harvesting and transplanting is now routinely done. Labor requirements often conflict with those for other crops. For example, labor required for plowing DWR fields is at the same time needed to prepare for early wet-season cash cropping in rainfed lowland rice fields (Lando and Mak 1994b).

Bhuktan's Nepalese study (Bhuktan 1990) shows that the average household combines 75% of household labor; 18% exchange and 7% hired labor. Seventy-nine percent of labor is allocated for staple food and rice received the maximum labor allocation. More than half of the households plow with their own oxen; 35% use exchange animals and 12% hire animals. Pure Brahmins have cultural taboos against plowing land with oxen so they hire non-Brahmins. Mountain households use more exchange labor than in the Terai where more hired labor is used. Furthermore, mountain crop farm is three-fifth female labor while Terai is three-fifths male labor.

In Madagascar, labor is increasingly hired; communal cooperative efforts are minimal or nonexistent. Exchange labor continues only in smaller, usually poorer but more egalitarian communities (Fujisaka 1990).

Thailand's response to the tighter labor market is mechanization. Farmers tend to hire others for almost every farming task. Farmers also rent out the land to those who have smaller farms or lower quality land because the latter have smaller land-labor ratio than the former. This results in an active land rent market. In the dry season farmers will also rent out part of their land for vegetable and water melon growers. The largest group of farmers tends to grow the least labor-intensive crops so it will have more time for nonagricultural employment (Poapongsakorn 1994).

Vietnam's underlying principle of equality among households was applied in the reallocation of field crop land. Tenants who make up about 12% of total farmers practice leasing-in to use more labor or leasing-out for those who have insufficient labor. Market transactions also enable farmers to consolidate their landholding in accordance with their farming capacity and eliminate the prevalence of tiny, scattered plots to promote large-scale farm operations (Chung and Weber 1994).

Exchange labor has practically disappeared in Philippine lowlard-rice but some of it is still practiced in the uplands. But the most important change in labor arrangements is the shift in rice harvesting systems, from the share of the threshed crop for the harvester (*hunusan*) under an open policy of every villager being allowed to participate in harvesting, to the *gama* system that limits participation in harvesting to those who weed for free in order to receive a share of the output of a certain plot (Hayami et al 1988).

Broadly speaking, family, exchange and cooperative labor are the major labor arrangements in unfavorable areas particularly in countries where decollectivization has taken place and where alternative nonagricultural employment is limited. However, hired labor paid in cash or kind has already taken over some specific tasks. Farm households practice 2 or 3 different labor arrangements for different farm operations, different crops and different ecosystems. For industrializing economies, hired labor has become the standard practice along with mechanization, leasing in or leasing out of land as ways of adjusting to labor shortage.

Gender roles in rice farming systems

Twelve years after the conference on women in rice farming systems, there is a host of studies providing empirically-based evidences from gender role studies in unfavorable areas in the Philippines, Indonesia, Thailand, Bangladesh, Nepal, India, Cambodia, Vietnam, Japan, and the Republic of Korea (Paris and Rosario 1993, Shinawatra and Pitackwong 1994, Paris et al 1992, Chi et al 1995, Alcober 1992), Morales et al 1993, Escalada et al 1992, Padermchai and Shinawatra 1992, Paris et al 1994a,b), Paris 1992, 1993, Paris and Carangal 1993). They tell us that women play a major role in rice farming systems not only in terms of physical labor, but also in supervisory and managerial roles. The significance of their role expands considerably when nonrice, off-farm, and nonfarm activities are taken into account. Rice farming systems owe their productivity and continuing viability to women. Because women are not exempt from traditional female household and family responsibilities as men seek off-farm employment, their active involvement in farming operations means that women now have two sets of full-time responsibilities.

Besides the general trend identified regarding the quantity of female labor input, there are several other research findings about fragile lives in fragile lands:

- Females from landless households spend more hours working as wage laborers in rice than females from farming households.
- The demand for female labor in nonrice and nonfarm activities is higher in unfavorable than in favorable areas.
- Of the total annual off-farm income, women contribute more than men. However in nonfarm activities, men spend more time than women.
- Among female headed households their contribution to rice production is higher than male headed households.
- Stressed environments have consequences not only on rice yields but drought also affects people—especially women. With low productivity, men migrate in search of work and women have to take over the management of farms. In-

creasing the demand for female labor in rice production, processing, animal care, collection of animal fodder and fuelwood may lead to changes in cooking practices (fewer meals), less time devoted to child care and breast-feeding (Paris et al 1994).

- Although there are places where gender roles are rigidly defiined, Tisch and Paris (1994) found that labor substitution between Filipino farming husbands and wives occurs in response to economic pressures rather than restricted by predetermined gender roles. Work roles are more fluid than suspected.

Unlike many other gender studies, the WIRFS (Women in Rice Farming Systems) research program and network went beyond gender analysis and tried to identify and/or develop technologies which would make the role of women more productive, reduce drudgery, increase income and improve the knowledge, skills and status of women. In this regard, Paris (1994) asks the question: "Do agricultural technologies help or hurt poor farm women?" Her reply is:

> Assessment of the employment implications of labor saving has to be done in a holistic sense rather than within the marginal confines ofthe the farm operations under question. In several instances, reduction in labor for one operation may lead to an increase in labor for other operations and hence the net effect on employment may be smaller than originally perceived. Also, people, especially poor households, are flexible, they move and adjust as market opportunities open up.

What does the future hold for agricultural labor and rice farming systems in unfavorable areas? In an analysis of agricultural diversification and commercialization, Pingali (1994) concludes that:

> The opportunities for dry season diversification in the rainfed lowlands and the deep water areas is limited by water availability. A similar situation is faced by upland areas which depend on level and distribution of rainfall. It is important to remember that even with increased commercialization and diversification trends, rice will continue to be the most imporant staple food in Asia, in relative and absolute terms.

The Republic of Korea best exemplifies this pattern. According to Park (1994), the crop area for rice has remained virtually constant at 1.2 million hectares for the past 30 years but agricultural labor has declined as rural-urban migration accelerated. By 1990, 18% of 6.7 million farmers were over 60 years old and 34% of farmers were between 20 and 50 years old. Younger and better educated household members have migrated out of the rural community, leaving women and elderly people in farming. Accompanying this reduction in the agricultural labor force is increased mechanization, fertilizer use and cost of farm labor. Similar trends can he observed in Thailand (Poapongsakorn 1994) and Indonesia (Pasandarad and Syaka 1994) as nonagricultural employment opportunities expand. Of course Japan started on this path much earlier. Kada and Kada (1985) show a predominance in part-time farming while the labor force is aging and the proportion of women in the older age groups is also increasing. Ohki (1985) points out that despite mechanization, the number of hours devoted by women per household per year has remained unchanged since 1965. As a result, accidents caused by machinery and chemicals have frequently occurred and health problems caused by the increase in stress due to the rapid change of technology and life style have appeared. Farm women have three urgent demands: more chances to acquire knowledge and skills for better agricultural management; guarantees of individual free time; and security in old age

On the issue of gender, nothing can be more fascinating than to find out what is happening to farm women in countries moving toward a market economy.

Sharing and managing genetic resources

One virtue of fragile lands is the diversity they offer in terms of rice varieties, growing conditions, varietal preferences and uses, and crop and farming system mixes. Not many farmers purchase seeds. They usually plant seeds from previous harvest or exchange with neighbors and friends on a shared and reciprocal basis. At the moment, we do not know much about the dynamics of informal rice seed systems and seed exchange and how farmers manage genetic diversity at the farm level. We find it rather curious that seeds which are the source of life of plants and of people have not received as much research attention. The relatively new interest in the relationship of seed health and seed management to crop yield is therefore a welcome addition to the research agenda. We hope the social components of seeds, particularly on fragile land, will be incorporated in this agenda. We must better understand how seeds function as medium of exchange and as a way of maintaining diversity.

At the international level, plant genetic resources (PGR) might be the last of our common heritage that is still being shared and INGER (International Network for

Genetic Evaluation of Rice) is a beautiful illustration of humanity working together for our common future in a world filled with social conflicts, tribal wars, and fierce competition over control of natural resources. We must continue to share even as countries declare national sovereignty over PGR.

Fragile lives in fragile lands: a capsule scenario

Our review of eight scenarios in fragile lands in rice-growing countries leads us to the following observations and extrapolations:

- There are contraindications to the arguments for concentrating research resources only on irrigated systems. The latter are showing signs of vulnerability while unfavorable areas, despite their fragility have become the destination of those in search of a place to live their lives even in poverty. These ecosystems are not likely to fade away in the foreseeable future.
- As a bridge of interdependence between the rural and urban sectors, rice is increasingly being consumed more by the urban than the rural population and proportionately more by the nonpoor than the poor. The urban poor have limited purchasing power while the rural poor do not harvest enough to eat. In the meantime, urban remittances support farm households and even purchase of rice inputs.
- Rice growing is part not just of a cropping or farming system but of a livelihood system which includes nonfarm sources and social mechanisms for coping with food insecurity.
- Seasonal calendars reflect periods of plenty and of scarcity; of malnutrition; of labor demand; of cash flows; of illness; of migration in search of work; of feasts and celebrations, etc. Rhythms of life are determined by the interrelatedness of livelihood sources; of caste and class and the household's stage in the family life cycle.
- A purely rice-growing household probably will not survive in an unfavorable environment. At the household level, there are diverse uses of land; diverse tenure systems for different crops, livestock, and trees in different ecosystems, often in more than one parcel of land not always contiguously located.
- The agricultural labor situation in several countries can be characterized by the phenomenon we labelled people plenty but labor short. Labor constraint, which is a problem repeatedly cited, has implications for the nature of technologies that will be developed and assessed for their adoptability.
- Without any doubt, women contribute substantially not only to rice production, but also to nonrice, noncrop, off-farm, and nonfarm activities in addition

to traditional household roles. But even more significant in urbanizing societies is the tendency for the young and educated to migrate to the city, leaving behind older men and women to do the farming. This picture of an aging labor force accompanied by increasing feminization of farming is taking place in Japan and the Republic of Korea. Thailand and Indonesia seem to be on a similar path. For countries on the road to market economy, the impact on women's roles can amount to a major social transformation.

- The social aspects of seed sharing and exchange and the dynamics of on-farm management of genetic diversity are little understood. It could be an exciting venture to deliberately promote something like a local INGER along the lines of traditional reciprocity.

Is there a role for social science? Along with biophysical characterization of ecosystems, we must find patterns in livelihood systems; develop quality of life profiles against which farming practices will be diagnosed and doable technologies designed interactively with those who are expected to adopt them. All these together will hopefully provide us the state of human well-being and will enable us to assess the likely and actual impact of any changes introduced and/or adopted. With the availability of analytical tools for dealing with complexities, the task should not be an impossible one. At any rate, we have already done the easy things.

Spectacular successes in the past three decades may not be replicable in unfavorable environments but incremental changes can make a lot of difference where low productivity, degrading resource base, and poverty are everyday facts of life.

Finally, if our shared mission is one of working to sustain the poor, feed the hungry, and protect the environment, nowhere can this mission be best and most directly operationalized than in fragile lands where fragile lives await the fulfillment of promises for a better life. For most of them, life can never be better without rice. They deserve the best of science and scientists to take them there.

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Six

Sustaining food security for fragile environments in Asia: achievements, challenges, and implications for rice

M. Hossain

Rice is the staple food and the principal crop in humid and subhumid Asia. The monsoon climate and the high temperature during periods of heavy rainfall favor rice cultivation in this region. From the Philippines In the east to eastern India in the west and from southern China in the north to Indonesia in the south, rice accounts for 30-50% of agricultural incomes and provides 50-80% of calories consumed by the people. Because of its importance in providing national food security and generating employment and income for the low-income people in society, rice is regarded as a political commodity and an important component of culture in many countries in Asia.

Achieving self-sufficiency in rice production and maintaining price stability are important political objectives, particularly in low-income countries due to 1) lack of foreign exchange to finance major international purchases, and 2) political sensitivity of rice prices. Even the prosperous East Asian countries have tried to maintain self-sufficiency in rice production by providing price support to rice farmers through protection of the domestic market.

Most Asian countries have done remarkably well in meeting the food needs of the growing population over the last quarter century. Many large rice-importing countries, such as India, Indonesia, Bangladesh, and Philippines, have achieved self-sufficiency in rice production and Vietnam has become a major rice exporter. But in developing countries, population is still growing at an alarming rate, and the absolute yearly increase in population in the 1990s is the highest in the history of humanity. As the demand for food grows with the increase in population, many land-scarce Asian countries will find it difficult to sustain the gains they have made in achieving food security.

This paper maintains that the challenge to sustaining food security will be particularly difficult for the countries with a large proportion of area under unfavorable rice-growing environments. The second section reviews the past achievements in the availability and distribution of food, and assesses the impact on alleviation of poverty and food insecurity in Asia, while the third section assesses the situation for diffirent rice ecosystems. The fourth section takes up the challenge to sustaining food security in different parts of Asia by looking into the long-term prospect of increasing rice supplies with existing technology to meet the growing demand for food. The fifth section draws implications of emerging trends for rice research for unfavorable environments.

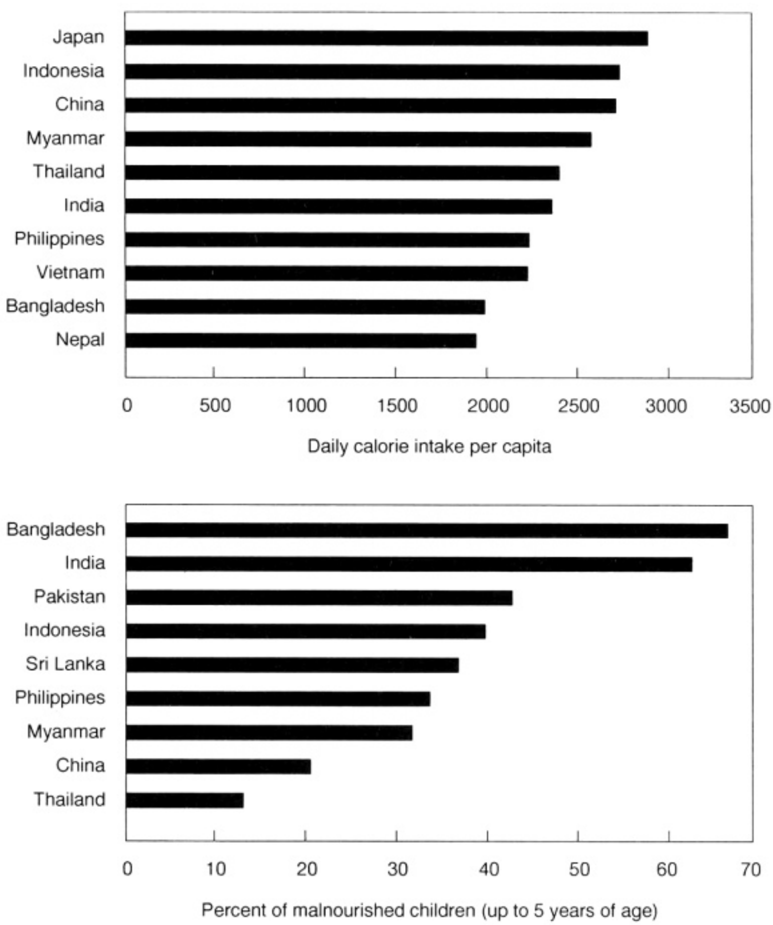
Achievements in rice production and food security

Before the 1960s, the growth of rice production was slow and originated mostly from the expansion of cultivated land (Barker and Herdt 1985). The growth in rice yield was mainly limited to the humid subtropics and temperate zones of the East Asian countries, where irrigation infrastructure was already developed. In South and Southeast Asia, rice yield was low and stagnant and the increased demand for rice was met primarily by expanding the cultivated area.

The green revolution in the humid and subhumid tropics in Asia was triggered by the introduction of IR8 in 1966 (Hossain 1994). Over the last three decades rice production increased at 2.4% per year, four-fifths of the growth was due to the increase in rice yield (1.9% per year) made possible through gradual replacement of traditional varieties (TVs) by modern ones (MVs) developed in rice research stations. Over this period, Asian population increased by 80% but rice production increased by 101%, and per capita rice consumption increased by 15%. Many large rice-importing countries such as India, Indonesia, and the Philippines achieved self-sufficiency in rice production, and Asia's share of global rice imports fell from 60 to 20%. Vietnam became the third major exporter rice in the world market, as economic liberalization policies induced rapid growth in rice production in 1980s (Pingali and Xuan 1992, Hossain 1994).

Food security, however, means access by all people at all times to enough food for an active healthy life (Reutlinger 1987). Its essential elements are the availability of food and the ability to acquire it. Although food may be available at the national level, a segment of the population may not have the capacity to acquire it because of the lack of employment opportunities, low productivity of labor, and low wage rates and incomes (Sen 1987). People may suffer from seasonal and transitory food insecurity because of fluctuations in food production and incomes due to variable climatic conditions.

The green revolution contributed to achieving food security mainly by inducing a decline in real rice prices. The new technologies increased the dependence of farmers on irrigation and chemical fertilizers, and substantially increased the cost of production per unit of land. But the increase in yield has been much higher than the increase in cost, and hence the cost per unit of output has declined. The cost and returns studies for selected Asian countries show that the cost per ton of rice output is about 20 to 30% lower in MVs compared to TVs, and in irrigated compared with rainfed rice (IRRI 1991, FAO 1993). Since rice is a basic necessity, the price elasticity of demand is low, and hence when supply increases faster than demand, the price declines disproportionately. Thus, the benefits of higher efficiency in the use of inputs and low unit cost of production that the MVs and improved farming practices have generated, have quickly passed on from farmers to consumers in the form of lower prices. The price of rice adjusted for inflation declined by nearly 40% over the last three decades (Fig. 1). The fall in prices has benefited the urban laboring class and the



1. Child malnutrition and calorie intake, selected Asian countries, 1992.

rural landless much more than the upper income groups, because the former spend a much larger proportion of income on rice than the latter.

In some countries, the decline in rice prices has been higher than the reduction in the unit cost of production, implying that the rice farmer who produces for the market faced a decline in profits per unit of output. Policymakers are concerned that this might affect the farmers' incentives to grow more food, and hence the long-term sustainability in the growth of production. But we should recognize that the adoption of MVs enables the farmer to increase rice yields two to three times higher than TVs, and the development of irrigation facilities needed tor the adoption of MVs facilitated double-cropping of rice in many areas. Thus, farmers are now getting 8-10 t of rice/ha per year compared with 2.0-2.5 t/ha when they cultivated traditional varieties under rainfed conditions. With this large increase in output from the same size of farm, the household income from farming has increased despite the decline in profits per unit of output. The increase in the productivity of the rice land and improvement in efficiency in input use contributed by rice research has thus protected the interests of both rice consumers and farmers.

But there is no reason to be complacent about past achievements. Asia is still the home of the largest absolute number of poor and chronically undernourished people (World Bank 1992). The average energy intake of the Asian people has reached closer to the level of the developed countries only in South Korea, China, and Indonesia. In Bangladesh, India, Nepal, Philippines, and Vietnam daily intake is still below the 2400 kilocalories considered minimum to lead a healthy productive life (Fig. 1). Over 60% of the children in India and Bangladesh suffer from malnutrition; the figure is 30 to 40% for Indonesia, Philippines, Myanmar, and Sri Lanka. According to the World Bank, two-thirds of the estimated 1.1 billion poor people in the developing world live in South Asia and Southeast Asia (World Bank 1992). About 40% of the world's poor live in India alone, while India's share of the developing world's population is 21%.

Differential performance across rice ecosystems

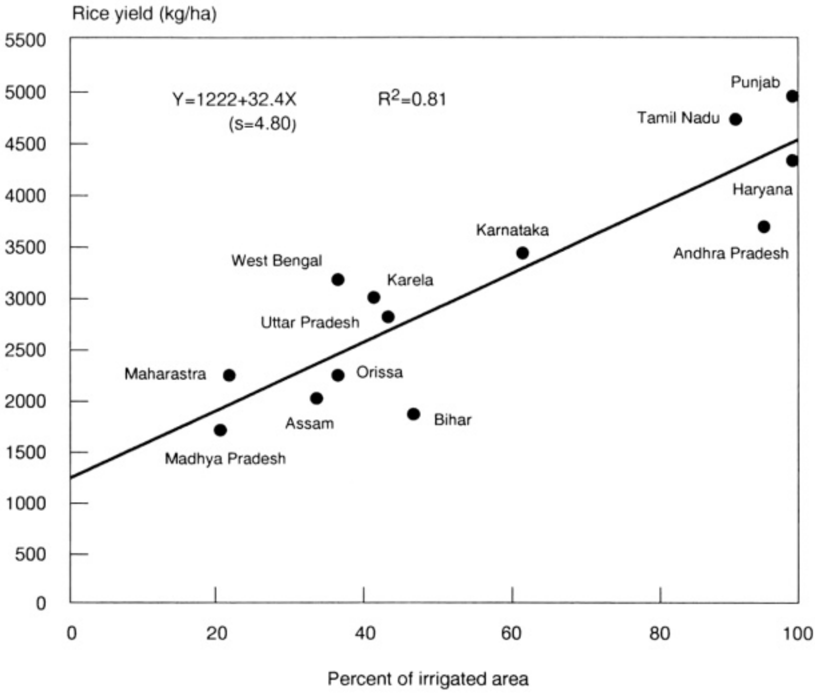
A main factor behind the existence of widespread poverty and malnutrition amidst self-sufficiency of foodgrains at the national level is the regional differentiation in the growth in rice production and the problem of distribution of rice among surplus and deficit regions.

Large parts of Asia, particularly the uplands and rainfed lowlands, are yet to benefit from the green revolution technology, as scientists have had limited success in developing appropriate high-yielding rices that can adapt to floods, droughts, temporary submergence, strong winds, and problem soils that characterize these ecosystems.

The available modern varieties may do well in normal years, but perform poorly compared with traditional varieties if there is a prolonged drought or sudden submergence of the plant due to vagaries of the monsoon. Thus, the rice farmer goes for modern varieties and intensive cultural practices when there is good irrigation and drainage facilities, or the rainfall is certain and evenly distributed throughout the growing season. Where the rainfall is unreliable and the risk in cultivation is high, farmers are still growing traditional varieties and use fertilizer in small amounts.

The increase in rice production over the last three decades has come mainly from 1) the adoption of modern varieties on the existing irrigated land, and 2) large-scale public and private investment on irrigation, flood control, and drainage for conversion of the rainfed ecosystem to irrigated to facilitate the adoption of modern varieties and improved farming practices. The present rice yield is about 5.0 t/ha for the irrigated ecosystem, compared with 2.3 t/ha for the rainfed lowland, 1.5 t/ha for flood-prone, and 1.1 t/ha for the upland ecosystem (IRRI 1993). The difference in yield across countries for specific rice ecosystems is low, but there are large inter-country variations in average yield at the national level because ot the ditterence in the composition ot the ecosystems. For example, in China the average yield is 5.8 t/ha compared wth 2.7 t/ha in India, mainly because in China 93% of the rice area is irrigated, compared with 45% in India. In many districts with dependable irrigation facilities in Indian Punjab, Tamil Nadu, and West Bengal, the average farm level yield has reached 5.5 t/ha, closer to the level in fully irrigated areas in China and Indonesia. In India itself the variation in rice yield across states is highly correlated with the proportion of area under irrigation (Fig. 2).

Because there are no time series data, we cannot review the trend in rice production by ecosystem. We have, however, classified the rice-growing countries and the states and provinces in India and China into three groups—mostly Irrigated (over 90%), largely irrigated (50-90%), and largely rainfed (less than 50% irrigated)—and estimated the growth in rice production and the sources of the growth. The largely irrigated countries have achieved a rate of growth of production at 3.0% per year, three-fourths of which came trom the increase in rice yields (Table 1). These are the regions that expanded their irrigation infrastructure to take advantage of the modern rice technologies, and that also increased rice harvested area as the raising of two rice crops during the year was possible. The mostly irrigated group (the East Asian countries) already had high rice yields at the beginning of the green revolution but still managed to increase the yield by 2.1% per year over the last three decades. The rice yield for this group increased from 3.1 t/ha in 1964 to 5.6 t/ha in 1991 (Fig. 3). For the rainfed group, the growth has been only 1.4% per year, much slower than the rate of population growth. A large part of the increase in production came from the expan-



2. Association between intensity of irrigation and rice yield in selected Indian states, 1991-92.

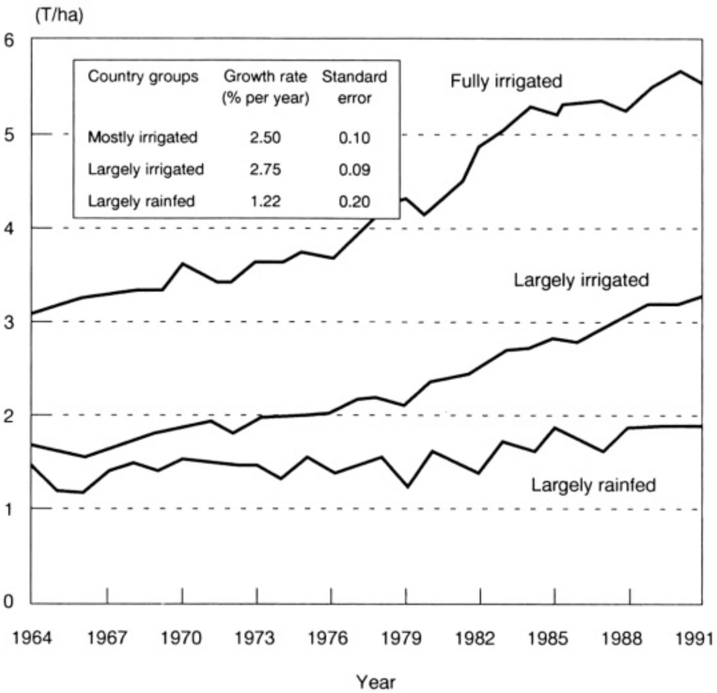
Table 1. Growth in rice production (% per year) in Asian countries classified by the extent of irrigation, 1964-93.

Country groups	Area	Yield	Production
Mostly irrigated (>90%)	0.3	2.1	2.4
Largely irrigated (50-90%)	0.7	2.3	3.0
Largely rainfed (<50%)	0.5	1.2	1.7
Asia	0.5	1.9	2.4

Source: author estimates.

sion of area under rice cultivation. The yield increased only marginally from 1.4 to 1.8 t/ha during the 1964-91 period. The growth in yield was also unstable compared with the other groups (Fig. 3).

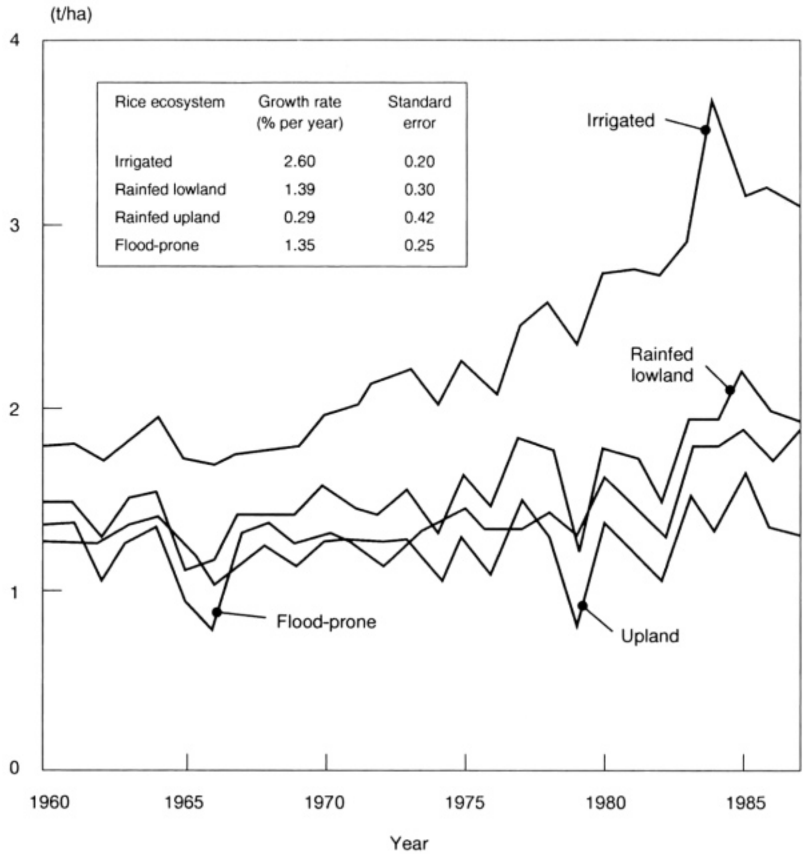
We also classified Indian districts into the four rice ecosystems on the basis of their dominant characteristics with respect to irrigation and flooding depth (Huke and Huke 1987) and estimated the trend in rice yield (Fig. 4). The growth in rice yield has been respectable only for the irrigated ecosystem (2.6% per year) and has also been relatively stable with a variation of 0.2% from one year to another. For the rainfed lowland and flood-prone ecosystems, the growth in rice yield has been only



3. Trends in rice yield by rice ecosystem, 1964-1991.

1.4% per year, with larger yearly variations. The yield has remained almost stagnant in the upland ecosystem and also has been most unstable.

The state level data for India shows a significant association between the extent of poverty and the level of yield in foodgrain production (Fig. 5). Poverty is more acute in regions such as Bihar, Orissa, and Madhya Pradesh, where the foodgrain yield has remained low and the growth has been slower than in more progressive states such as Punjab, Haryana, and Tamil Nadu. At low levels of income, staple foodgrain production is a major economic activity in rural areas and the main source of employment and income for the people. The expansion of the rural nonfarm sector, which could provide alternative job opportunities, depends on the growth of agricultural production (Hossain 1988, Haggblade and Hazell 1989, Haggblade and Liedholm 1992). The slow growth in productivity in rice has kept rural employment and incomes at low levels and has constrained the economic capacity of people in unfavorable ecosystems to acquire food that is produced at a lower cost in the irrigated ecosystem.



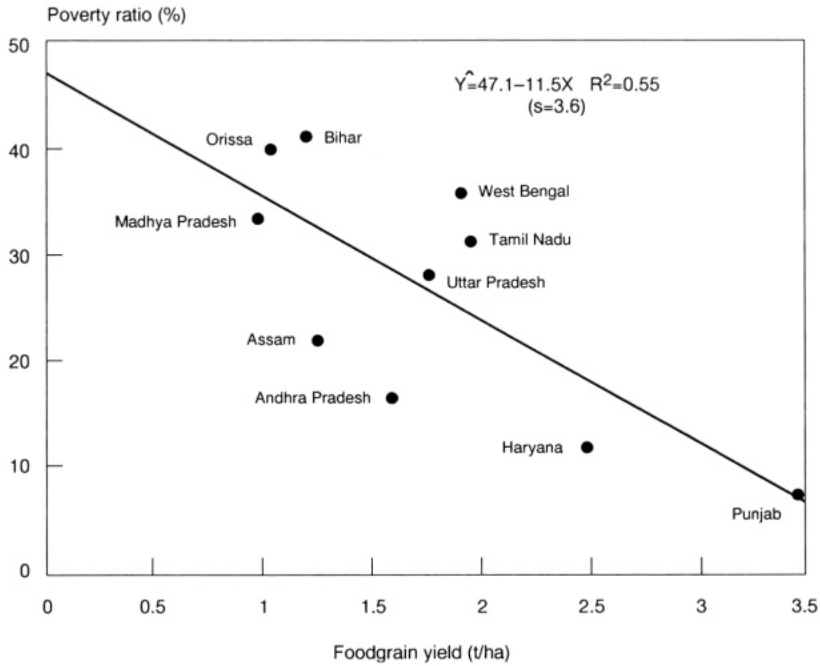
4. Trends in rice yield by rice ecosystem, India 1960-1987.

Emerging demand and supply trends and the challenge of sustaining food security

The problem of sustaining food security over the long-run is how to ensure increase in food supplies to meet the growing demand, and to maintain the capacity of all sections of the population to acquire that food.

The growth in the demand for a particular food item depends on 1) the level of per capita income and the rate of its growth, 2) the rate of growth of population, and 3) the change in relative prices among different food items.

At low levels of income, rice is considered a luxury commodity. With increases in income, people tend to substitute low-cost sources of energy, such as coarse grains and sweet potato, for rice. But at high levels of income, rice becomes an inferior good. As incomes rise further, consumers go for a diversified diet and substitute high-cost qual-



5. Trends in foodgrain yields and poverty level in rice-growing states in India.

ity food, such as vegetables, bread, fish, and meat, for rice. Japan, South Korea, and Taiwan have already passed through these phases and have experienced a decline in per capita rice consumption after reaching a high level in the mid-1970s. Recently, Malaysia and Thailand are facing the same experience. But these high- and middle-income countries—where rice consumption has been declining—account for less than 10% of total Asian rice consumption. The income threshold at which higher quality and more varied foods are substituted for rice has not yet been reached in China, India, Indonesia, Bangladesh, Philippines, and Vietnam. Recent estimates of income elasticities of demand suggest that with every 10% increase in per capita income, the expenditure on rice may increase by 0.8% for Thailand and the Philippines, 1.2% for India, Bangladesh, and Indonesia, and 1.9% for China. These countries account for more than 70% of total rice consumption and dominate the growth in demand for rice in the world. Thus, with increases in per capita income and alleviation ot poverty, there would be some income-induced growth in demand for rice, in future.

But the major force behind the increasing demand for rice in the future is going to be the continued high growth of population. The Asian population is expected to increase by 18% during the 1990s, and by 53% in the next 30 years. Most ot the additional population will be located in urban areas and the marketed surplus of rice has to increase to meet the growing urban demand. Recent projections show that, at prevailing price levels, the demand for rice may increase by 69% by 2025, most of it due to feeding a larger population. This means that Asian rice production must increase to more than 800 million t over the next 30 years, from the present level of about 480 million t.

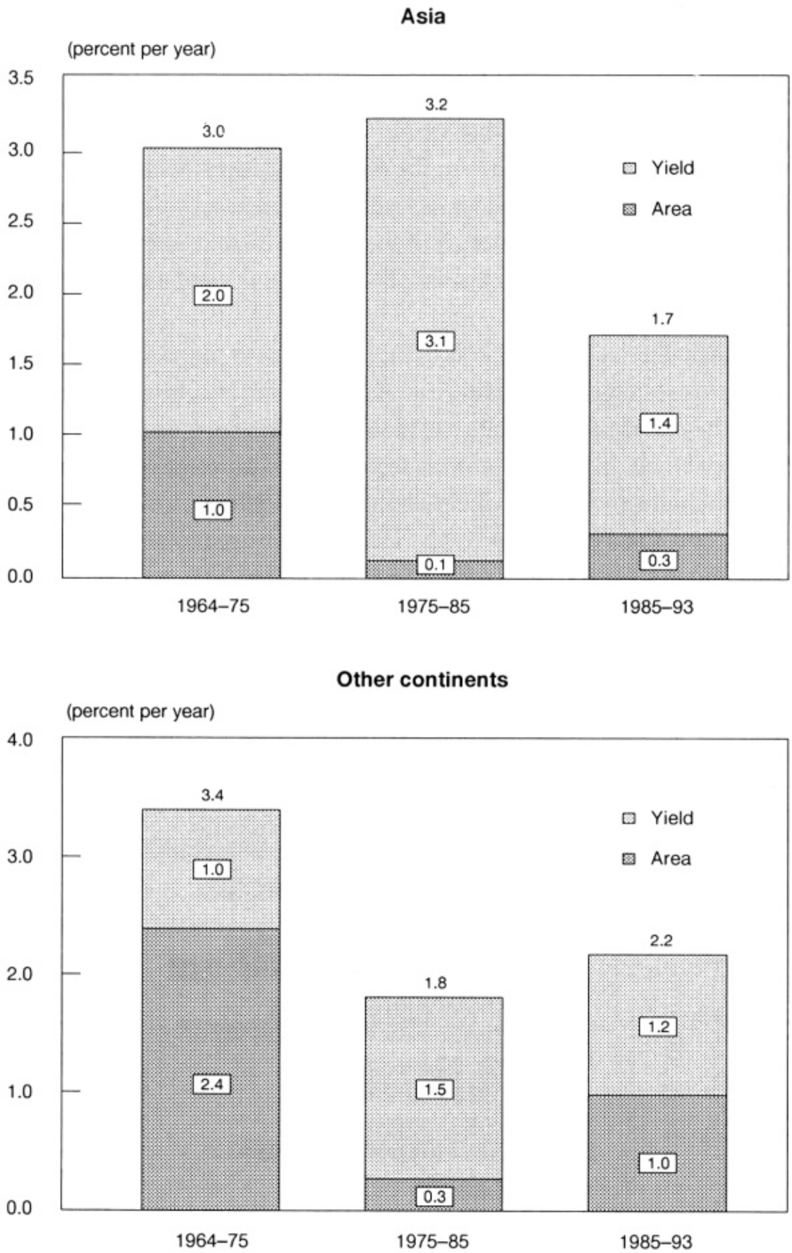
Without a continuing growth in rice productivity, it will be difficult to ensure growth in rice supplies of this magnitude. As the economy grows, prime rice land is being lost to accommodate industrialization and urbanization. Salinization and degradation of irrigation infrastructure are reducing both the area under irrigation and the quality of irrigated land. In China, the rice area harvested declined from 37 million ha in 1976 to 32 million ha in 1992; in the Philippines, it declined from 3.7 to 3.2 million ha within the same period. As rice area is expected to decline in the future, rice yield has to increase faster to meet a targeted increase in rice supply.

Recent developments, however, suggest that yield growth has started to decline and reversing the trend will not be easy. In the irrigated rice ecosystem, which accounts for almost three-fourths of total rice supplies, most farmers have already planted high-yielding modern varieties and the best farmers' yields are approaching the potential that scientists are able to attain with today's knowledge in that particular environment.

Most of the increase in rice yields in favorable environments was achieved through investment in irrigation and flood control that allowed intensive utilization of agrochemicals on genetically improved varieties. But the cost of irrigation has increased substantially, as easy options have already been exploited (Gershon and Keek 1994). Also, the concerns for the adverse effects of irrigation and flood-control projects on the environment have been growing. Already, there has been a drastic decline in investment for the development and maintenance of large-scale irrigation projects in many Asian countries.

A deceleration in the growth in rice supply has already set in. The annual growth in global rice production was only 1.7% per year during the 1985-93 period, compared with 3.2% during 1975-85, and 3.6% the decade earlier (Fig. 6). The recent growth of rice production was less than the population growth in the Philippines, Myanmar, Thailand, and China. In the last decade, only in Vietnam, Indonesia, Bangladesh, and India has rice production grown at a respectable rate.

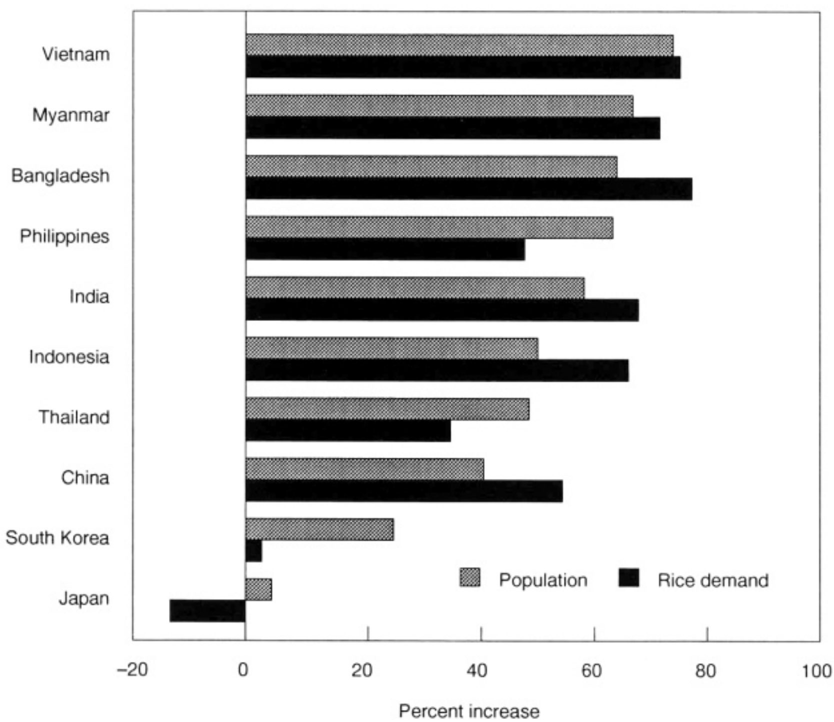
The challenge to sustaining food security wil1 be more difficult for the lower income countries in Asia, which have a large proportion of area under unfavorable rice growing environments. With the alleviation of poverty, the per capita food consumption is expected to increase in these countries as people try to meet their latent demand for food. The experience of economic development shows that the lower the



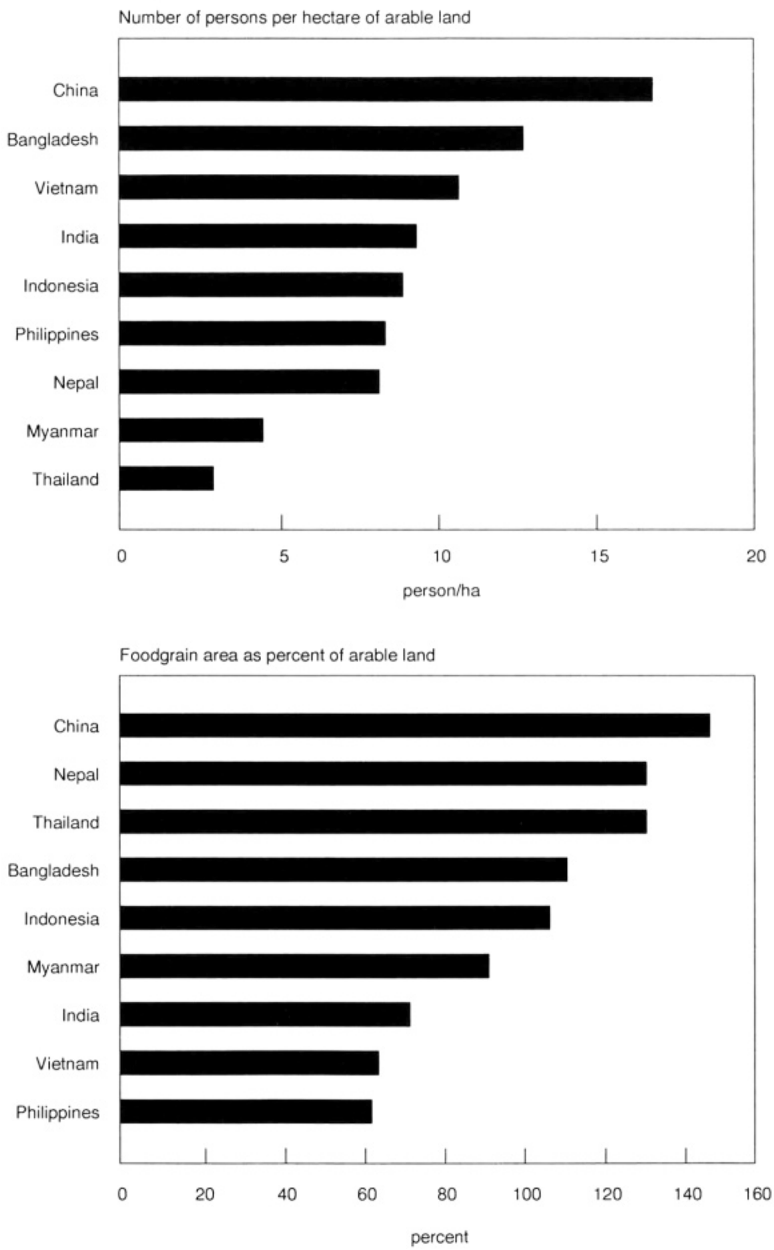
6. Growth of rice production in Asia and other continents.

level of income, the higher the rate of population growth and that the success in population growth comes with economic prosperity. The low-income countries of South Asia and Indo-China are expected to experience much higher rates of population growth and demand for food than the middle- and high-income countries in East and Southeast Asia. The demand for rice will remain almost the same in South Korea and will fall by 15% in Japan because of the decline in per capita consumption, but will increase by over 70% in Bangladesh, Myanmar, and Vietnam, and by 60-70% in India and Indonesia (Fig. 7).

The natural resource constraints to increasing rice production are severe also for most of the low-income countries in Asia. As the frontier of cultivable land was closed long ago, the per capita availability of arable land has been declining rapidly with growing population. In the rice-growing region, China now supports 17 persons/ha of arable land; the figure is 13 for Bangladesh, 11 for Vietnam, and 8 to 10 for India, Indonesia, and the Philippines. Only Thailand, Myanmar, and Cambodia have favorable endowments of land, with 2 to 4 persons/ha. The population pressure is reflected in the high cropping intensity for foodgrains production. The cropped area



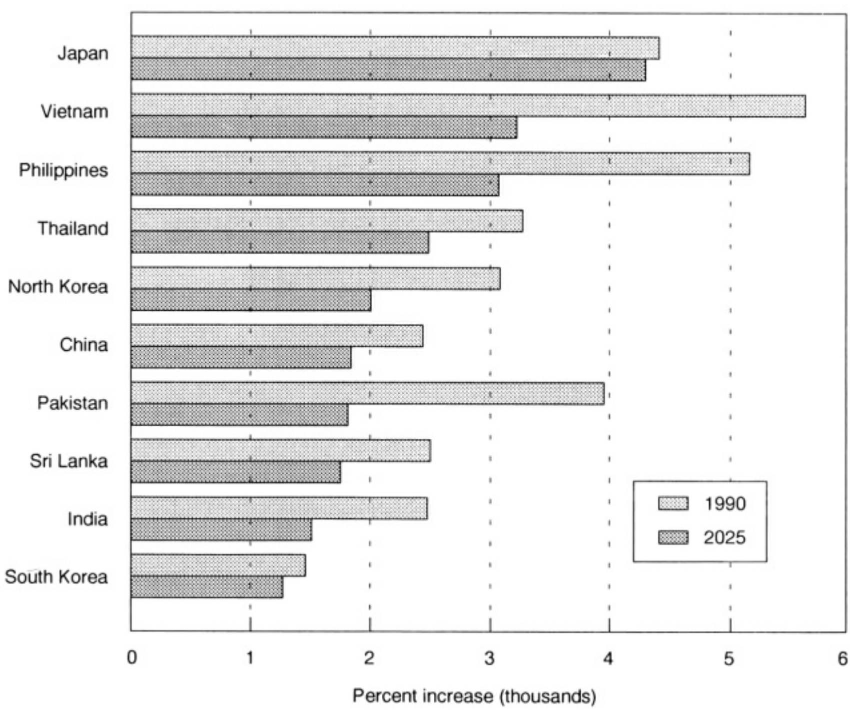
7. Projection of population growth and the demand for rice, 1990-2025.



8. Population pressure and intensity of landuse for foodgrain production in selected Asian countries, 1992-93.

under foodgrains per unit of arable land is 148% for China, 132% for Bangladesh, 112% for India, and 108% for Vietnam, compared with about 60% for Thailand and Myanmar (Fig. 8). There will be economic pressure to release riceland in favor of vegetables, fruits, and fodder, whose market becomes stronger with economic progress.

Water, which is usually regarded as an abundant resource in humid Asia, is also becoming a scarce commodity. In absolute terms, annual water withdrawals are by far the greatest in Asia, where agriculture accounts tor 86% of total annual withdrawal compared with 38% in Europe and 49% in North and Central America (WRI 1992). The per capita availability of water resources declined by 40 to 60% in most Asian countries over the 1955-90 period (Gleick 1993). By common convention, countries are defined as water scarce when per capita availability is less than 100 m^3, and as water stressed when the availability is between 1000 m^3 and 1700 m^3 per capita. China, India, Sri Lanka, Pakistan, and South Korea are expected to reach near stress levels by the year 2025 (Fig. 9). There is a need to reduce water consumption in rice cultivation and devise ways for harvesting and more efficient utilization of rainwater.



9. Projected change in per capita water resources in selected Asian countries. Source: Gleick (1993).

It is true that a country need not have self-sufficiency in rice production to achieve or sustain food security. In Asia, Singapore and Hong Kong produce very little foodgrain but have better records of food security than the major rice growing countries of South and Southeast Asia. Malaysia meets almost 40% of its rice needs through imports. What is important is achieving food self-reliance. It is favorable export growth at the national level that permits deficit countries to import food from those with a surplus and, at the household level, productive employment and adequate incomes to acquire the needed food from the market.

As per capita rice consumption declines with economic growth, the middle- and high-income countries of Asia should have some surplus rice available tor exports to the low-income food deficit countries. In Japan, peak rice harvest reached 18.8 million t in 1967, but started to decline from that level and reached about 12 million t in 1992. In Taiwan, China the peak reached 3.6 million t in 1976 while the present production is only about 2.0 million t. These countries could have maintained their production levels through exports of surplus rice to other countries, but they could not compete in the world market with other exporting countries. With economic growth, land, labor, and water became more expensive and the cost of rice production went up in spite of more efficient use of these inputs (through improved crop-management practices) and saving of labor through mechanization in rice cultivation. In 1987, the unit cost of rice production (US$ per ton) was about 20 times higher in Japan and seven times higher in South Korea than in Thailand (Table 2). As competition for scarce inputs grew with the development of the nonfarm sector, wage rates and land prices continued to increase and rice farming became uneconomic. More and more farm household members took up nonfarm employment and became part-time rice farmers. The government has encouraged the rice farmers to divert land to other crops, but they were not as profitable (Kada 1992). The government raised rice prices through protecting the domestic market, and provided farm subsidies in order to keep the balance between rural and urban household incomes (Park 1993, 1994). Thus, having an export surplus from middle and high-income countries in Asia seems highly improbable.

There is considerable potential for expansion of the rice area in the humid tropics of Africa and Latin America. It is estimated that there are 20 million ha of inland valleys in West Africa alone of which only 15% are currently cultivated. In tropical South America, an additional 20 million ha of land may come under crop production by year 2010 (FAO 1993). But the cost of rice cultivation is many times higher in Africa and Latin America than in low-income Asian countries (Table 2) because of labor scarcity, high wage rates, and poor infrastructure facilities. When food-deficit households have low income and surplus labor that cannot be productively employed

Table 2. Rice yield and unit costs of production, selected countries.

Country	Season/type	Rice yield (t/ha)	Cost of production (US$)	
			Per ha of land	Per t of output
Bangladesh[a]	Wet Season	3.37	327	97
	Dry season	4.56	513	113
Vietnam[b]	Autumn	3.80	353	93
	Spring	5.35	333	62
China[a]	Early season, indica	5.34	416	78
	Middle season, indica	6.49	399	62
	Japonica	6.58	513	78
Indonesia[c]	Irrigated	5.76	474	82
	Rainfed	3.57	389	109
Thailand[c]	Irrigated	3.78	369	98
	Rainfed	1.84	223	121
Colombia[c]	Irrigated	5.61	1144	204
	Rainfed	4.71	914	194
Costa Rica[c]	Irrigated	4.33	1020	236
	Rainfed	3.71	1117	301
Burkina Faso[c]	Irrigated	4.73	1707	361
	Rainfed	2.50	720	288
Zambia[c]	Irrigated	5.00	5515	1103
	Rainfed	2.50	808	323
Korea, Rep[c]	Irrigated	6.50	4348	669
Italy[c]	Irrigated	5.87	3188	543
Japan[c]	Irrigated	6.51	12935	1987
USA[d]	Long grain	5.94	1339	225
	Medium grain	8.57	1889	220

Sources: [a]Obtained through personal communication. China for 1991 and Bangladesh for 1993. [b]FAO, Rice Policy in Vietnam for 1993. [c]Yap (1991), for 1987-90 period. [d]USDA-ERS for 1991.

elsewhere, they would use that labor to produce food by themselves, rather than acquiring high-cost food from the market. Thus, the African and Latin American countries will find it difficult to compete with the low-income Asian markets.

Thailand, Myanmar, and Cambodia have considerable excess capacity to meet potential shortages in other countries in South and Southeast Asia, and the cost of production will remain competitive for some time at least in Myanmar and Cambodia. If rice prices go up, farmers will be encouraged to increase rice production by investing in irrigation and chemical fertilizers, and adopting higher yielding varieties. But achieving food security through international trade may not be possible, because of foreign exchange constraints in the low-income, food-deficit countries. Also, since rice production is a major rural economic activity at low levels of income, and land and labor cannot be easily diverted to other economic activities during the monsoon season, low-income households may find it difficult to acquire imported food. If economic conditions of small farmers and landless laborers fail to improve due to stagnant productivity of the most important economic activity, the increase in rice prices will only aggravate the poverty situation in the food-deficit countries.

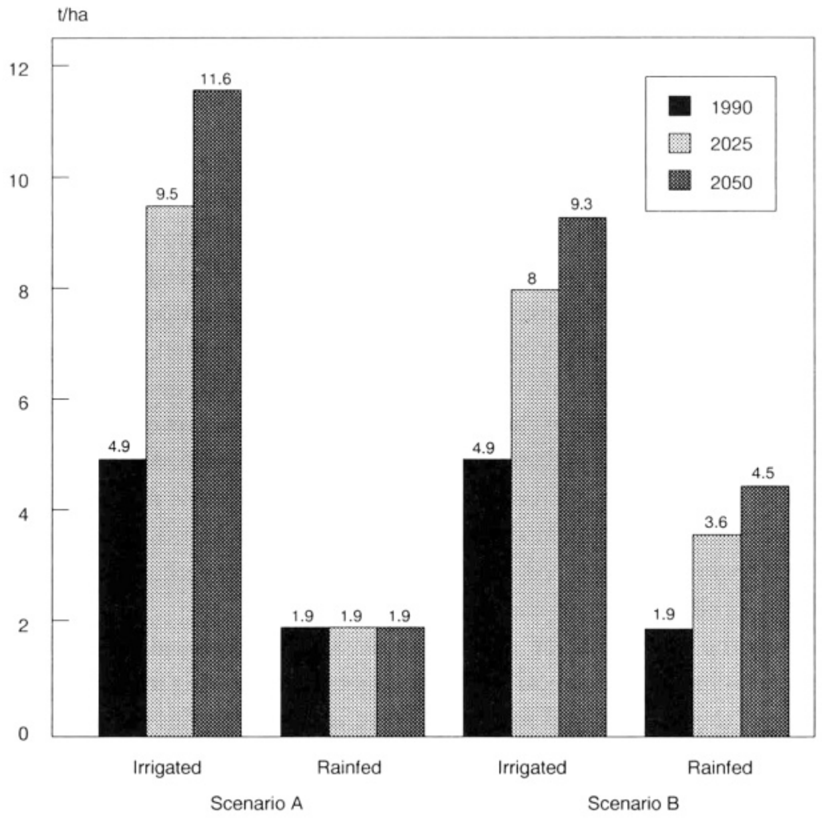
Implications for rice research

The success of increasing rice outputs in the 1970s and 1980s was based on a research approach of developing a genotype that could express the full yield potential and had resistance to major insect pests and diseases. It was assumed that the constraint to wider adoption of the technology imposed by variations in environment (different water regimes, soil conditions, etc.) would be taken care of by investments in irrigation and drainage, and use of chemical fertilizers. It kept the cost of research low and helped provide rice to the urban poor at affordable prices, but gradually increased the gap in rice productivity between the favorable and unfavorable rice ecosystems. As markets failed to distribute food between surplus and deficit areas at terms at which the poor could access that food, food insecurity, and poverty persists amidst relatively plentiful supplies at the national and global level.

With the increase in the intensity of rice cultivation based on irrigation and ever-increasing use of chemical fertilizers, concerns are growing regarding the maintenance of the quality of soil and water. There are signs that this system may not be able to support present output (Cassman and Pingali 1995) let alone the increases needed to meet the growing long-term demand. If 1) progress in raising yield for the rainfed ecosystem remains low, which has been the experience of the past three decades, and 2) there is no further expansion of irrigation and area under rice cultivation to ensure sustainability of the natural resource base, rice yield in the irrigated ecosystem must increase to 9.5 t/ha by year 2025 from the present level of 5.0 t/ha. That will require application of nutrients from outside sources by an additional 200 to 250 kg/ha, which even if technically feasible, can impose substantial negative side-effects on the environment. If rice science can help increase farmers' yield in the rainfed system from 2 to 4 t/ha, the pressure on the irrigated ecosystem will be reduced, the increase in yield required falling to about 8 t/ha (Fig. 10). These are hard scientific challenges.

To address the problems of unfavorable rice ecosystems, the concept of rice research should change from "thinking globally and acting globally" to "thinking locally but acting globally". This will require a systems approach in conceptualization and conduct of rice research, and effective partnership between national and international scientists to better understand the nutrient-water-plant interaction for efficient exploitation of the resource base in homogeneous agro/ecoregions.

The rainfed ecosystems share one major characteristic—uncertain moisture supply. Fields may have too much water, too little water, or both, within the same crop-



10. Required increase in yield to meet the projected demand for rice for the years 2025-2050.

ping season. The monsoon may come late or stop early, and although there may be adequate rainfall during the entire growing season, the distribution may not be tuned to the needs of the rice plant. The uncertainty and risk in rice cultivation, and the adverse impact of crop failures on the sustainability of the resource base for subsistence living compels resource-poor farmers to go for less-intensive management practices and for traditional cultivars that can withstand the variable environments. Work to enhance productivity must focus on understanding processes and mechanisms that give traditional cultivars capacity to withstand the abiotic stresses, and use this knowledge to develop high-yielding cultivars with more stable yields (Zeigler and Puckridge 1995). Appropriate crop models are needed to simulate growth for variable environments and examine the effects of variable weather on yields.

A number of Asian countries have been involved in a systematic study of the farm-level constraints to increasing rice production during the collecting of information from experienced farmers and extension workers on their perceptions regarding yield losses from, and the frequency of occurrence of, various biotic and abiotic stresses. The synthesis of the findings show that abiotic stresses are relatively more important constraints than biotic stresses and that drought, submergence, weeds, nutrient deficiency, stemborer, blast, acidity, and bacterial blight account for more than 80% of the production losses in rainfed lowland and upland ecosystem. Thus, besides developing resistance in modern cultivars to common insects and diseases, rice scientists should focus their attention to understanding the mechanism of tolerance to prolonged moisture stresses and sudden submergence from flash floods, heavy rains, and tides.

The rainfed system is characterized by diversified cropping and economic activitics. As the household struggles to survive, members try to exploit every available economic opportunity—from raising multiple crops on the same land in different rotations to participating in both farm and nonfarm activities depending on the seasonality of agricultural activity. Efficient use of land, labor, and water for increasing and stabilizing household incomes will require, under these production conditions, a fundamental understanding of system dynamics, including farmers' traditional practices and indigenous knowledge, and the interventions that rice research could make tor increasing productivity at the system rather than the crop level. For example, developing early vigor in the rice plant, drought resistance during the vegetative stage, and a more cost-effective method of weed control could induce farmers to go for crop establishment through direct seeding with pre-monsoon rains, rather than the traditional practice of waiting for the heavy rains needed for puddling the soil for transplanting of tall seedlings. This would not only allow the rice plant to avoid the late season drought, but also permit the dry season crops that follow rice (coarse grains, oilseeds, and pulses) to gain from residual moisture in the tail end of the monsoon season (Zeigler and Puckridge 1995). Successful systems analysis and manipulation will require new efforts at farm level participatory research, and crop and systems simulation modeling linked to geographic information system.

Conclusions

Research problems in unfavorable ecosystems are more complex and challenging than those for the relatively homogeneous irrigated ecosystem. To make headway on them will require mobilizing the best of science and the best of scientists in national agricultural systems, international centers, and advanced institutions in industrialized countries through partnership research. Research relevance and effectiveness will depend on close collaboration among research partners, selection of key sites, and the mechanism of partnership research. It is true that the rate of return on research investment will not be as high as that obtained in the past through targeting irrigated ecosystems, because of the lower probability of research success and smaller extrapolation domains of research outputs. But the trade-off is worth considering in view of the continuing problems of poverty and hunger and of sustaining food security for the fragile environments in Asia.

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SEVEN

Natural resource and environmental consequences of rice production

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Rice production occurs in four agroecological environments: irrigated, mostly in lowlands; rainfed upland and lowland areas; and so-called flood-prone areas along rivers and in deltas where production is based on annual flooding. The natural resource and environmental consequences of rice production in the four environments depend in part on the levels of production in those environments. These levels, in turn, depend on global demands for rice and on the percentage share of each environment in satisfying those demands. These shares reflect the competitive strength of the several environments relative to one another in satisfying rice demand. The four environments thus constitute an integrated production system. Consequently, assessment of the natural resource and environmental consequences of rice production in any one of the environments must take account of the consequences in the others as well.

This perspective dictates the structure of this paper. I begin with a brief sketch of a global demand scenario for rice, although because 90% of rice production and consumption is in Asia, essentially the scenario is tor that region. Other chapters treat future demand in detail (e.g., Chapter 6).

A demand scenario

Rice "utilization", which includes all uses of rice, not just that for human consumption, rose at an average annual rate of 3.5% per year from 1975-76 to 1980-81. at 2.7% per year from 1980-81 to 1985-86, and at 1.6% per year from 1985-86 to 1991-92 (USDA 1992). The falling rate of increase in utilization over the 16-year period occurred despite a decline in the price of rice.

Mitchell and Ingco (1993) project that global consumption of rice will continue to increase at an average rate of 1.6% from 1990 to 2010. This rate is the same as the United Nations medium projection for world population over that period. Mitchell and Ingco thus implicitly assume no global increase in per capita consumption of rice over the 20-year period. But 90% of global rice consumption is in Asia, so it is more useful to compare the Mitchell and Ingco projection of consumption with the UN's projection of population in Asia, which is 1.5% per year between 1990 and 2010 (UN 1991). The Mitchell and Ingco projection thus probably implies some small increase in per capita rice consumption in Asia.

Mitchell and Ingco assume that per capita income growth in Asia will continue to be vigorous (as do Agcaoili and Rosegrant 1994), so it is plausible to believe that any increase in per capita rice consumption in Asia over the next decade will be small. The reason, as Mitchell and Ingco (1993) argue at some length, with many citations to the literature dealing with changing patterns of per capita rice consumption in Asia, is that as per capita income rises from very low levels per capita rice consumption at first increases, but then levels off and eventually declines as consumer preferences shift to wheat and animal products, and fruits and vegetables. In the Mitchell and Ingco scenario, per capita consumption of rice increases with rising income in some very poor developing countries, but in others with higher income, per capita consumption levels off or declines. The net outcome is the above-mentioned projection of no change in per capita consumption between 1990 and 2010 on a global scale, and probably no more than a small increase in Asia over that period. Agcaoili and Rosegrant (1994) project global demand for all grains to increase 1.6% annually from 1988 to 2010. Like Mitchell and Ingco (1993), Agcaoili and Rosegrant argue that as per capita income increases above some level, per capita demand for rice grows more slowly than demand for other grains. In a number of important rice-consuming countries, per capita income is evidently above this level already, and by 2010 others also will probably exceed it. The Agcaoili and Rosegrant projection for all grains therefore implies less than 1.6% annual growth in global demand for rice between 1988 and 2010.

Crosson and Anderson (1992) projected rice consumption in the developing countries to increase 1.3% annually from 2005 and 2030. I now consider this projection to be too high. There are two reasons. The UN's medium population projection for Asia is 1% per year for 2005-2010 (UN 1991), so the Crosson and Anderson projection for rice in that period would imply some increase in per capita consumption (this assumes that almost all rice consumption will continue to be in Asia). Such an increase now seems implausible, given the argument of Mitchell and Ingco (1993) that, as per capita income increases, per capita rice consumption reaches a peak, then levels off or declines.

The second reason I now think that the Crosson and Anderson demand projection for rice may be too high is an argument put by Seckler (1994) that the UN's low population projection for the 35 years 1990 to 2025 is more likely than its medium projection, the one used by Mitchell and Ingco (1993). Seckler asserts that the principal reason for the differences among the UN's high, medium, and low projections is different assumptions about rates of fertility decline in developing countries. Seckler argues that the fertility rate assumptions underlying the UN's low projection are in fact more in accord with recent experience than those underlying either the medium or high projections. Moreover, Seckler argues, the "modernization" process as it bears on fertility is spreading rapidly in the developing countries. The major components of "modernization" are "... women's education and liberation, urbanization, rising per capita income, decreasing infant mortality rates, and, not least, radio and television" (Seckler 1994). According to Seckler, the recent spread of modernization has been at a pace hardly imaginable even a decade ago.

The UN's (1991) low projection has global population increasing at 0.8% annually during the 2005-25 period. On the plausible assumption that per capita rice consumption would decline over this period, total consumption would grow at something less than 0.8% annually, substantially less than in the Crosson and Anderson (1992) projection of 1.3%

This view of the future suggests that the problem of increasing rice production at satisfactory economic and environmental costs in response to rising demand will be more severe over the next decade than over the subsequent period. That is to say, achieving a satisfactory response to annual demand growth at 1.6% over the next decade should be more difficult than in the 10 or 20 years after that when annual demand growth now looks to be 1% or less. Given this aspect of the demand scenario, the main focus of the discussion here is the period to 2005.

Rice production environments

Rice production environments are classified as irrigated lowlands, rainfed lowlands. rainfed uplands, and flood-prone. Estimates ot the amounts of land and production in each environment vary slightly, depending on the source. Table 1 gives a composite set of estimates drawn from several such sources.

The environment of irrigated rice production

Over 90% of irrigated riceland is in Asia (Barker and Herdt 1979). In China and other parts of East Asia, virtually all rice land is irrigated (Barker and Herdt 1985). China, with a little over 30 million ha of irrigated rice (FAO 1991) accounts for about 40% of all irrigated rice land and for almost 45% of such land in Asia. Of the some 80 million ha of rice land in South and Southeast Asia (USDA 1992), about one-third is irrigated (Barker and Herdt 1985). Although irrigated rice production is found across all agroecological regions, it is concentrated in the subtropical regions of Asia (Zeigler et al 1994).

From Table 1 it can be calculated that, at 4.8 t/ha per year, irrigated rice yields are twice the yields in rainfed lowlands and flood-prone environments, and four times the yields in rainfed uplands. The main reason for the yield differences, of course, is that in rainfed and flood-prone systems the high yielding modern varieties (MVs) of rice and the associated technology, e.g., high levels of fertilizer, usually are not profitable to farmers, while in irrigated systems they are highly profitable. It is no surprise, therefore, to find that in the mid-1980s MVs were planted on 95% of the land under irrigation, but on only 40% of rainfed lowlands, and not at all on rainfed uplands and flood-prone systems (Byerlee 1994a).

Between 1965-67 and 1990-92 global rice production increased 95% and area harvested increased 17% (USDA 1992). The increase in area therefore accounted for 18% of the production increase, and higher yields, reflecting the widespread adoption of MVs and the associated technology on irrigated land, accounted for 82%. Over the 10 years from the mid-1960s to the mid-1970s yield growth averaged 2.0% annually, then accelerated to 2.5% from the mid-70s to the mid-80s. After the mid-80s, however, yield growth declined sharply, falling to 1.4% per year from 1984/86 to 1992/94 and to 1.1% from 1988/89 to 1992/94 (USDA 1993).

Yield is the average return to only one input, land. Its declining rate of increase would not necessarily be troubling if returns to other Inputs were increasing enough that total productivity, the ratio of output to all inputs, continued to rise at a satisfactory rate. But this seems not to have been the case. Evidence indicates that, in the 1980s, total productivity growth in much of rice-growing Asia leveled off and then declined (Byerlee and Pingali 1994, Cassman and Pingali 1995). Moreover, these estimates of total productivity include only marketed outputs and inputs. If costs of unmarketed damages to the environment, e.g., from erosion, were included among

Table 1. Estimates of land areas and rice production from irrigated lowlands, rainfed lowlands, rainfed uplands, and flood-prone ecosystems.

Land type	Production			
	Million ha	% of total	Million t	% of total
Irrigated	78	53	378	73
Rainfed lowlands	38	26	88	17
Rainfed uplands	19	13	23	4
Flood-prone	12	8	29	6
Total	47	100	518	100

Sources: Total land and production are 3-year averages for 1990-92 from USDA (1992). The distribution of the totals among irrigated, lowlands, and uplands is based on IRRI (1992a,b, 1993). The numbers for flood-prone are residual differences between the totals and the sums of the three other environments the inputs, the growth of total productivity likely would have been less and its subsequent decline more pronounced.

The collapse of the rate of increase of yields and total productivity for rice has aroused deep concern among researchers and policy people with responsibilities for the rice economy. Should the recent relatively low rates of yield increase persist, it would be impossible to meet the projected 1.6% annual increase in rice demand over the next 10 to 15 years without bringing more land into rice production. High and increasing land scarcity in much of Asia, the high costs of bringing more land under irrigation, and the likelihood of rising environmental costs with additional land clearing in rainfed environments, suggest that expanding the area in rice would encounter rising economic and environmental costs prejudicial to the welfare of Asian societies.

Given the dominance of irrigation in total production, it seems apparent that the sharp decline in the rate of yield increase in the 1980s occurred mainly in irrigated areas, although I have not seen data bearing this out. The reasons tor the decline are much discussed in the literature but remain unclear. Pingali and Rosegrant (1994) identified two such reasons: 1) declining rice prices discouraged investments in new irrigation projects and in rice research and extension; 2) diminishing returns to fertilizer and other nonland inputs used in intensive irrigated rice production. Pingali and Rosegrant note that inflation adjusted prices of rice have been on a declining trend since the beginning of the century, with a particularly sharp decrease in the 1980s. The lower prices weakened farmers' incentive to apply more purchased inputs, which slowed the rate of yield and total productivity increase. The declining price trend also weakened Incentives for both public and private investments in irrigation for rice production, and for public investments in research and extension.

These economic factors could plausibly account for the slowing rate of increase in yields up to the mid-l980s, but it is not so clear that they explain the sharp fall in the rate since then. One would expect the negative yield effects of declining Investments in irrigation, research and extension to be gradual, not precipitous. And Pingali and Rosegrant (1994) do not present data on the amounts of purchased inputs applied by farmers before and after the mid-1980s so one is not able to judge the likelihood that decline in those inputs could account for the sharp post-mid-1980s decline in yield and total productivity growth since the mid-1980s.

It is interesting to note that the collapse in the rate of yield increase after the mid-1980s coincided precisely with an almost equally sharp decline in the rate of increase in rice utilization. This is a bit of a puzzle. Given the decline in the increase in utilization, it is not surprising to observe a comparable decline in the increase in total production (USDA 1993). But why should the decline in the rate of production increase take the form of slower yield growth, not a slower increase in the amount of land? Perhaps the answer—this is pure speculation—is that the institutional conditions of water supply and management on irrigated land in Asia make it more attractive to farmers to reduce, or slow the increase, in production, when market conditions call for that, by reducing applications of nonland inputs, thus reducing yield growth, than by reducing the amount of land in production.

Whatever the answer to the question, the temporal association of the decline in yield growth with the decline in the growth of utilization suggests that at least some of the disappointing yield performance since the mid-1980s is explained by farmer responses to the demand side of rice markets. That is part of what Pingali and Rosegrant (1994) said, although they did not make the particular demand side argument made here.

As already mentioned, Pingali and Rosegrant (1994) also single out environmental effects of long-term, intensive cultivation as a factor in accounting for the decline in the rate of yield growth. "Long-term intensive cultivation" here means continuous cultivation on the same land of two or three crops of rice per year over a couple of decades. Production under these conditions leads to "1) build-up of salinity and waterlogging; 2) micronutrient deficiencies and increased incidence of soil toxicities; 3) formation of a hardpan (subsoil compaction); 4) decline in soil nitrogen supplying capacity; and 5) increased pest build-up and pest related yield losses" (Pingali and Rosegrant 1994). In their discussion of these effects Pingali and Rosegrant make a persuasive argument why the effects can develop under long-term continuous rice production and why they would adversely affect yields. The authors do not, however, tie the development of the adverse effects to the specific experience with rice yield growth over the last several decades or, more specifically, show why the effects would cause the observed precipitous decline in yield growth since the mid-1980s.

The list of five adverse environmental effects on yields discussed by Pingali and Rosegrant does not include sedimentation of irrigation systems resulting from soil erosion. The authors, however, assert that such sedimentation has occurred in parts of Asia and has reduced the service area of irrigation systems. Pingali and Rosegrant link this result to the decline in rice prices relative to prices of other crops, saying that the consequent switch to other crops intensified pressure on land in the upper watersheds of irrigation systems, leading to increased erosion and downstream sedimentation damage.

It is argued that erosion and resulting sedimentation also has significantly damaged irrigation systems for rice production in China, particularly in the northeastern part of the country (Huang and Rozelle 1993). Deforestation resulting from population growth is given as the reason for the increase in erosion. According to Huang and Rozelle (1993), officials in Guangxi Province "claim that more than 20% of their provincial irrigation systems have been destroyed or completely silted up by erosion, leading to large declines in grain yields". The area affected by salinity problems increased from 7.3 million ha in 1985 to nearly 7.6 million ha in 1990 (Huang and Rozelle 1993). These numbers represent about 25% of China's irrigated rice area, but the increase of 300,000 ha from 1985 to 1990 seems too small to have had much effect in reducing the rate of rice yield increase in China since the mid-1980s.

Like Pingali and Rosegrant (1994), Huang and Rozelle (1993) argue that increasing the intensity of rice production, such as moving to 2 or 3 crops a year, can reduce yields or yield growth by diminishing soil nutrient supplies, increasing soil toxicity from use of pesticides, and increasing soil compaction by more use of tractors. A study reported by Nambiar (1994) found the same negative yield effects of intensification in the Indian State of Orissa.

The literature describing the negative yield effects of increasing intensification of rice production ascribe these effects to unfavorable changes in environmental conditions of production, e.g., salinity build-up, problems of maintaining soil nutrient supplies, increasing problems with insects, weeds and disease, etc. From an agronomy standpoint, It is quite appropriate to call these unfavorable changes "environmental" since the changes are in qualities of the soil, water, and pest populations. From the standpoint of environmental economics, however, the environmental changes are only those that impose costs on others than those that are responsible for them. The productivity losses imposed on downstream farmers by increasingly saline irrigation water passed to them by upstream farmers are an example of an environmental cost as economists understand the term.

Byerlee (1992) gives two other example of such environmental costs in the Indian Punjab. Much irrigated production in that region is by drawing water from an aquifer that underlies the area. The water is a "an open access" resource, meaning that no individual or group has a property right in the water so no one can exclude anyone else from using it. The consequence is that no farmer has incentive to take the future value of the water into account when deciding how much to pump "today" because the farmer has no assurance that such conserving behavior will increase the supply of water available to him "tomorrow". With every farmer acting in this way, the amount of water pumped each year from the aquifer is socially excessive. From the economic standpoint, this is an "environmental" cost because by his action each farmer imposes economic costs on all other farmers, and on future generations to whom water will be more scarce, and hence more costly.

The other example Byerlee (1992) gives of an environmental cost of irrigated production in the Indian Punjab is the increased health risk imposed on nonfarm users of groundwater polluted by infiltration of nitrates or pesticides from farmers' fields. The increased risk represents an environmental cost because the risk is borne not by the farmers responsible for the groundwater pollution but by others who drink the water.

The intensification of irrigated rice production involved a rapid increase in the use of pesticides, particularly insecticides. Herbicides, because they substitute for labor, were largely confined to East Asia, except China, where rural wage rates where relatively high, and rising (Barker and Herdt 1985). It is plausible that the increased use of insecticides would have imposed higher environmental costs, i.e., damage to others than the farmers who applied the insecticides, but convincing documentation of this is hard to find. In a study of consequences of insecticide use in the Philippines, Antle and Pingali (1994) found that the materials significantly injured the health of the farmers and farm workers who applied them, with consequent negative effects on productivity. These productivity losses, however, are economic, not environmental costs of insecticides because the losses occurred on the farms where the insecticides were used.

Note that the risk of insecticide use in the Philippines studied by Antle and Pingali was the same as the risk of groundwater pollution reported by Byerlee (1992) in the Indian Punjab: a threat to human health. However the threat in the Punjab represents a true environmental cost, while that studied by Antle and Pingali is an economic cost. The difference is that, in the Punjab, the threat is not to the particular farmers responsible for it, while the pesticide threat is borne by the farmers and the labor they may hire who apply the pesticides.

Of course the distinction between environmental and economic costs in these two cases is of no importance to the people whose health may actually have been impaired. The distinction is important, however, for understanding the incentives that lead farmers in the Punjab to down play, it not ignore, the threat and those studied by Antle and Pingali (1994) to necessarily take it into account in deciding about the use of pesticides. Understanding these incentives, in turn, is a condition for devising policies to reduce the threats.

Many of the costs imposed by deteriorating environmental conditions under intensified rice production are economic, not environmental, as economists use these terms. The costs are part of the on-farm costs of production in the same sense as the costs to the farmer of labor, fertilizer, machineny and other inputs that he buys or provides himself. Farmers thus have incentive to control or reduce the damages incurred by intensified irrigated rice production. That they have so far not succeeded in doing so—at least that seems to be the message of yield performance since the mid-1980s—must reflect lack of understanding of the problem, or lack of the resources needed to act on the understanding.

In any event, there are strong arguments for believing that the increased intensity of rice production in lowland irrigation environments in Asia contributed to slower yield growth in the 1980s, thus tending to increase production costs, whether the costs are considered to be environmental or economic. As they stand, however, the arguments do not seem sufficient to explain the sharp drop in the rate of yield increase over the last 7 or 8 years, unless there is some kind of threshold yield effect of increasing intensification which was passed in the mid-1980s. The literature reviewed in preparation of this paper revealed no such threshold. The explanation ot the rice yield experience since the mid-1980s thus remains elusive, although the economic and environmental factors identified by Pingali and Rosegrant (1994) seem likely to prove important in whatever explanation finally emerges.

Rainfed lowland environments

Table 1 indicates that in the early 1990s these environments accounted for 38 million ha (26%) ot total land in rice and for 88 million t (17%) of total production. In South and Southeast Asia about one-third of rice land is in rainfed lowlands (IRRI 1992b).

In the mid-1980s rainfed lowland rice yields averaged 2.3 t/ha per year, about half of yields on irrigated land. The literature reviewed for this paper did not indicate the yield experience of rainfed lowland rice over the last couple of decades, but yields on some of this land must have increased because by the mid-1980s some 40% of lowland rainfed riceland was planted to MVs (Byerlee 1994a). The MVs have not been adopted more widely in this environment because over about two-thirds of the area (Fujisaka 1990) the climate is adverse, soils are poor, many of them suffering particularly from deficiencies of phosphorus and zinc (Zeigler et al 1994), and poverty among farmers makes it difficult for them to buy the fertilizers and other inputs needed to make cultivation of the MVs profitable (IRRI 1992b). Where MVs have not heen adopted such production increase as has occurred has heen through bringing more land under cultivation. Cropping intensity has not increased; neither has per capita production. Nonagricultural development in these non-MV area has been sluggish, not enough to absorb all entrants to the labor force, which has put downward pressure on wage rates (Zeigler et al 1994).

Among the environmental limitations of the rainfed lowlands the variability of rainfall may be most important in inhibiting wider adoption of MVs. Precipitation is sufficiently erratic that over a few years farmers may face conditions varying from severe drought to damaging floods. The resulting uncertainty weighs heavily in the decisions farmers make whether to adopt MVs, and sharpens the risk of severe loss where many farmers already are living close to the margin of subsistence (IRRI 1992a, Fujisaka 1990).

A study of more than 6 million ha of rainfed rice farming in Cambodia, Lao PDR, Thailand, Nepal, and Madagascar found farmers confronting these various adverse environmental conditions and coping with them more or less well, albeit at a low level of productivity (Fujisaka 1990). Yields were low, and not tending to increase. Soils generally suffered from deficiency of micronutrients and low pH. Most farmers fertilized with farmyard manure. Supplies of this resource, however, are diminishing because animal numbers are declining as farmers shift land out of pasture and forest to produce crops. Moreover, deforestation has increased the demand for manure as fuel.

Population growth in the rainfed lowland areas is inexorably leading to more intensive use of those lands. Farmers are shortening tallow periods to plant more rice, and other crops (IRRI 1992a). Zeigler et al (1994) assert that increasing intensification of production in these areas can lead to the same pollution problems as in intensively cultivated irrigated areas. The authors do not say so but the statement presumably applies to the 40% of the rainfed lowland area where MVs are planted (Byerlee 1994a) since it is on that land that cropping intensity would be highest and the use of fertilizers and pesticides most pronounced. It is not clear in the Zeigler et al statement whether "pollution" means off-farm damages of rice production, e.g., through agrochemicals in runoff, or whether the damage is to the production site itself. In the first case "pollution" is an environmental problem (for economists); in the second it is an economic problem resulting from on-site degradation of the natural resource base.

Most of the natural resource problems associated with rice production in this environment seem not to be consequences of production but rather to be inherent in the environment itself, e.g., the uncertain precipitation and poor quality soils. Because production is rainfed, salinity build-up, and waterlogging cannot be major problems. Consequently, depletion of already scarce soil nutrients may be the principal effect of rice production on the natural resource base of rainfed lowland environments.

In the 40% of these environments where MV's are planted, there may be some environmental problems of agrochemicals in runoff, although I have seen nothing indicating that the problems might be serious. In the 60% of the area where MVs have not been adopted, it is a fair inference that the environmental consequences of production probably are small. The low per hectare use of fertilizers and pesticides supports the inference. And the relatively flat terrain on which production occurs in this area suggests that soil erosion, hence off-farm sediment damage, is not a major problem; at least it did not feature in the literature reviewed in preparing this paper.

Rainfed upland environments

In the mid-l980s, these environments accounted tor 19 million ha (13%) of total rice land and for 23 million t (4%) of total production (see Table 1). At 1.2 t/ha per year, average yields in these environments are only one-half those in rainfed lowland areas and only one-quarter of irrigated yields. Upland soils generally are well drained hut nutrient poor, and lack of soil moisture often is limiting to crop growth. Nearly 100 million people, most of them at subsistence income levels, farm in these upland environments (IRRI 1993).

The upland rice ecosystem in Asia is extremely diverse (IRRI 1993). Almost one-fifth of the rice area is on slopes of 0-8% and about one-tenth on slopes of more than 30%. Annual rainfall varies from 1-4.5 m and soils vary from highly fertile volcanic and alluvials to highly weathered, infertile, and acidic types. Phosphorus deficiency is a main constraint on many of these upland soils. Only 15% of the soils are of the fertile type. Rice is often planted on plots of less than 0.5 ha, with most of the work done by hand. Much of the rice area is in a shifting cultivation system with crops planted for 1 or 2 years and a rotation period to previously cleared land of 3 to 10 years. Weed control is probably the main biological constraint faced by rice growers in upland environments (IRRI 1993).

The poor growing conditions characteristic of the uplands and the poverty level of most of the rural population have totally discouraged the adoption of MVs and the associated technology in the area (Byerlee 1994a, IRRI 1993). Harrington (1993) describes the uplands of Asia as “fragile”, meaning that under cultivation they are vulnerable to irreversible damage, especially from erosion; that they are inaccessible to lowland markets for agricultural inputs and outputs; and that they are highly heterogeneous in their characteristics of climates, soils, terrain, and other natural features, which inhibits the specialization in cropping that would promote higher productivity.

By all accounts erosion is the most serious natural resource and environmental consequence of rainfed upland rice production. Zeigler et al (1994) assert that erosion is the primary constraint to rice production in the sloping uplands of Thailand, Indonesia, and the Philippines. The constraint is not only felt on the land where the erosion occurs. The resulting sediment loads may have severe negative effects on lowland areas as a result of siltation of reservoirs and drainage ditches, and increased flooding “... which can destroy very large lowland rice areas” (Zeigler et al 1994, IRRI 1992a). Zeigler et al (1994) and IRRI (1992a) attribute the increasing erosion in the rainfed upland rice environment to the natural fragility of the environment, combined with increasing population which, in the absence of technical change, has reduced fallow periods and spurred deforestation so that more land could be planted to rice and other crops. The argument is plausible. Yet the fact is that we have very little systematic and comprehensive information about how much soil erosion is occurring in Asia or what its soil productivity and environmental consequences might be. In a recent survey of present knowledge about the soil productivity effects of erosion in Asia, Dregne (1992) states that:

> Assessment of the permanent soil productivity loss due to human-induced erosion in Asia is handicapped by the inadequacy of the data base. National reports of erosion commonly deal in generalities, seldom cite sources of information, and rarely contain maps delineating affected areas. If soil productivity loss is mentioned the basis for the conclusion drawn usually is not stated.

With respect to China, Dregne states that, although most discussion of erosion and its consequences have focused on the loess soils of the northern plateau, there is a consensus that erosion is a problem in the hills of central and southern China also. Data confirming the consensus are hard to find, but an aerial view suggests that erosion in the hills and mountains of that region appears to be responsible for silt-laden streams in the watershed of the Yangtze river, east and southeast of the agriculturally important Sichuan Basin. There is an abundant literature on erosion of the loess plateau soils. Sheet erosion has not much damaged productivity on the these soils because they are so deep. Large-scale gullying clearly has reduced productivity on the gullied land, but the extent of the productivity loss is not known. Dregne cites studies in India indicating that some 57% of the countries cropland "needs" conservation treatment, but what "needs" means here is not clear. Although "no areas of erosion-induced permanent soil productivity loss in Southeast Asia can be specifically identified, there is little doubt that such areas exist. Thailand, Indonesia, Sarawak, and the Philippines certainly have experienced locally severe erosion and, probably, productivity loss" (Dregne 1992). Java, according to Dregne (1992), "...must be one of the most eroded places in Asia, if not the world". The Indonesian Government classifies some 1 million ha of cropland—about 8% of the total—as critically eroded, meaning that the land, if not now, then soon, is so badly degraded that it will be unable to sustain even subsistence agriculture. Extensive land clearing and cropping since the end of World War II have resulted in severe erosion in some parts of the Philippines, leaving, according to one report, some 9 million ha of the country's 13 million ha of cropland eroded to some extent. As elsewhere in Asia, however, the extent of the erosion-induced loss of productivity in the Philippines is not known.

A worldwide survey of land degradation done under the leadership of the International Soil Reference and Information Centre (ISRIC) in the Netherlands, showed that 38% of the cropland in Asia, 20% of the permanent pasture, and 27% of forest and woodland had suffered to some extent from human-induced land degradation. Over 80% of the degradation was due to water and wind erosion, with water erosion about twice as important as erosion by wind. The survey categorized land degradation as light, moderate, and strong/extreme. Olderman et al (1991) do not report the amount of land in each category in Asia, but on a global scale 38% of the land is lightly degraded (agricultural productivity reduced "somewhat", full restoration of productivity possible by local modifications in farming practices), 46% was moderately degraded ("greatly reduced" productivity, full restoration only with major improvements beyond the means of farmers in developing countries), and the rest (16%) strongly-to-extremely degraded (virtual total loss of agricultural productivity restoration generally beyond the means of developing country governments). Asia accounted for almost one-third of the land in the ISIRC survey, so the global percentages of degraded land by degree of degradation probably are reasonably representative of the situation in Asia.

Crosson and Anderson (1992) acknowledged the ISRIC survey as a major ad· vance toward improved information about laid degradation, but they raised a question about the degree of productivity loss involed in "moderate" degradation. The ISRIC survey classified much of the land in the American midwest in this category. Crosson and Anderson cited crop yield experience in that area over the last several decades and a study by Crosson and Stout (1983) showing very low erosion-induced losses of productivity there as evidence that the ISRIC survey probably overstates the severity of the erosion-productivity problem in that region. Crosson (1995) concluded that most of the global erosion-induced losses of soil productivity has occurred on the 16% of the land the ISRIC survey showed to be severely-to-extremely degraded.

Both the Dregne and ISRIC surveys deal specifically with productivity effects of erosion. Dregne nonetheless makes frequent references to the off-farm consequences of sediment originating on farmers' fields in Asia e.g., diminished water quality, siltation of reservoirs, increased flooding, etc. The off-farm, hence environmental, costs of sediment damages in Asia are no better known than the on-farm, hence economic, costs of erosion-induced losses of soil productivity. The available anecdotal evidence suggests to me that the environmental costs are higher than the economic costs, but this is only a guess.

The 19 million ha of rainfed upland riceland is only 3.5% of agricultural land in Asia (Oldeman et al 1991). However, upland areas generate substantially more erosion per hectare than land in general, so the contribution of rainfed upland rice production to total erosion in Asia must be more than 3.5%. Even if the contribution were double or triple that number, however, it still would be small relative to the total erosion problem in Asia. The upland areas, however, must be responsible for practically all the erosion resulting from Asian rice production generally. But, as the review of current knowledge about erosion and its consequences indicates, there is no present basis for judging how important the erosion-induced economic and environmental costs of rainfed upland rice production may be.

Flood-prone environments

In the mid-1980s, these environments accounted for 12 million ha (8%) of the global total of land in rice and for 29 million t (6%) of total rice production (see Table 1). IRRI (1992-93) estimates some 15 million ha of land in flood-prone rice. The difference between this estimate and the 12 million ha given in the text is not significant for this discussion. At 2.4 t/ha per year, flood-prone rice yields were about the same as in rainfed lowland production, about twice as much as rainfed upland yields, and half of yields on irrigated land.

Flood-prone rice is direct-seeded or transplanted in the rainy season in flood plains or in delta soils where flooding occurs to a depth of 50 to 300 cm (IRRI 1992a). Most flood-prone production is in the deltas of the major rivers of South and Southeast Asia (Barker and Herdt 1985). The crop grows as the flood water rises and is harvested after the water recedes. Because farmers have little control over the timing or extent of flooding, flood-prone rice production is subject to high uncertainty. This, and the fact that many delta soils suffer from salinity and toxicity problems, probably accounts for the fact that in the mid-1980s MVs were not planted in flood-prone environments. Byerlee (1994a) indicates zero use of MVs in these environments. Despite these generally unfavorable growing conditions, more than 100 million people are dependent on flood-prone rice production (IRRI 1992a).

The natural resource and environmental consequences of flood-prone rice production appear to be mild compared to the other three growing environments. Because MVs are not grown in flood-prone areas, use ot agrochemicals is quite limited. It seems a fair inference that environmental damage by these materials would be similarly limited. Given the relatively level terrain and conditions of production in flood-prone areas, erosion would not likely be a major problem. In any event it was not mentioned as a problem in the literature reviewed for this paper.

Potential of the four environments for meeting the demand scenario

Recall that in the demand scenario global rice consumption, mostly in Asia, grows 1.6% annually over the next decade, and at 1% or less in subsequent years. Because of the difference in consumption growth rates, I suggested that the next 10 years would present the major challenge to achievement of rice production systems able to meet rising demand at sustainable economic and environmental costs. I also indicated that the shares of the four environments in meeting the demand scenario would depend on how their relative economic and environmental costs respond to the pressure of rising demand.

Were it not for the still imperfectly understood fact of the sharp drop in the rate of yield increase in irrigated areas since the mid-1980s, one could confidently predict that most of the increase in production over the next decade would occur in these areas. It is fair to say that, given presently available technology, good water control is central to achieving high-yield, low-economic-cost rice production. Irrigated areas have a clear water-control advantage over rainfed or flood-prone areas.

But with demand for rice rising, it is the prospective behavior of marginal economic and environmental costs in the four environments that is relevant to their respective shares in satisfying the increase in demand. And the almost stagnant yield performance in irrigated production over the past 10 years raises a question whether the marginal costs of irrigated production still compare as favorably as they obviously once did with those costs in the other growing environments.

It would seem to be of major importance to determine to what extent the sudden and sharp decline in yield growth after the mid-1980s was a response to the coincident decline in demand, or whether it reflected the sudden emergence of unfavorable growing conditions resulting from increasingly intensive cultivation in irrigated environments. It the demand-side explanation accounted for the recent yield experience one could reasonably conclude that the experience reflected a rational response of rice producers to changing market conditions. In this case, there would be no particular reason to doubt that, should future demand conditions call for a faster rate of increase in yields, farmers would be able to respond accordingly. One would expect then that most of the increase in demand would be satisfied by irrigated production. However, if the recent yield experience fundamentally reflects supply-side problems, then the advantage of irrigated environments, relative to the other growing environments, would seems to be substantially less. The shares of those environments in satisfying future demand likely would increase.

If the yield problem arises primarily from supply-side factors then the question of research priorities among the four growing environments emerges much more sharply than it would if the problem reflected demand-side factors. For if the problem is on the supply side, the evolution of markets will not automatically ensure that production can be Increased on sustainable terms in response to the demand scenario. New knowledge will be required that will break the emerging supply bottlenecks.

This is not the place for detailed discussion of how research priorities should be set among the four production environments, a discussion which I am, in any case, not competent to undertake. A number of points suggest themselves, however. One is that rainfed upland rice environments present formidable obstacles of climate, soils, and terrain that would have to be overcome to obtain significant advances in productivity. Increasing production in that environment in ways that would contribute significantly to meeting rising demands for rice, and would be profitable to farmers, while avoiding higher risks of erosion and other environmental costs, likely would be difficult. Increasing at 1.6% annually from the early 1990s, global demand for rice would rise about 25% by 2005, or 130 million t of paddy. In the early 1990s, rainfed upland production was some 19 million t, about 4% of total production. Suppose that research made it possible for rainfed upland production to supply 10% of the increment of production needed by 2005, or 13 million t. Production in that environment would rise from 19 million t in, say, 1992 to 32 million t in 2005, an average annual rate of increase of 4%. Would such a rapid rate of production increase in that environment be feasible with even a major increase in research resources devoted to that end? And suppose the research undertaking succeeded. Ninety percent of the needed production increase still would have to be provided by some combination of expansion in the other three environments.

The same kinds of questions could be raised about a strategy emphasizing research to increase production in flood-prone environments, and for the same reasons, natural constraints to expanded output in that environment look formidable, and even a highly successful research program to overcome the constraints would contribute relatively little to the additional production needed to meet the demand scenario over the critical next decade.

Of course, if the research devoted to increasing output in the rainfed uplands and flood-prone environments had lagged badly over the last decade or so, the marginal returns to increased investment in those areas might be relatively high, despite their generally unfavorable growing conditions. But apparently research on those environments has not lagged. Byerlee (1994a) asserts that crop-breeding research devoted to fragile areas, which would include most of the rainfed upland and flood-prone environments, has been substantial, in some cases proportionally greater than the shares of these environments in total value added in production.

The rainfed lowlands look more promising. The fact that by the mid-1980s 40% of the land in that environment was in MVs (Byerlee 1994a) suggests that the natural resource and environmental constraints to the application of improved technology in the rainfed lowlands are less than in the upland and flood-prone environments. Writing in the late 1970s, Barker and Herdt (1979) stated that the total payoff to research in rainfed rice—most of which is in the lowlands—might be greater than that focused on irrigated rice. "There are indications that modest investments in research for rainfed rice to date has paid high dividends" (Barker and Herdt 1979). IRRI (1992b), while noting the adverse affects of climate and soils in rainfed areas, nonetheless asserts that "The world's rainfed lowlands offer tremendous potential for increasing rice production and for making rice farming an attractive enterprise".

Yet even with good success in increasing rainfed lowland production, it appears that the main burden of meeting the demand scenario over the next decade will fall on existing irrigated environments. The present size of this environment relative to the other three in percentage contribution to total production seems to point inexorably to this conclusion. Cassman and Pingali (1995) take this position, asserting that most of future increases in rice production "must come from existing intensive irrigated rice systems in Asia." They take the same position with respect to future increases in cereal production generally.

If the rice production increase needed is achieved at satisfactory economic and environmental costs, it almost surely would have to come through increased yields. The high costs of bringing more land under irrigation supports this conclusion as does the likelihood that in East and Southeast Asia growth in demand for nonrice food and for nonagricultural output probably will reduce the amount of irrigated land now in rice production (Zeigler et al 1994). If supply-side factors were primarily responsible for the decline in the rate of yield increase on irrigated land since the mid-1980s the challenge to research to reverse the decline would appear formidable. But it may make sense to think of alternatives in addition to crop-breeding research to confront the challenge. Pingali and Rosegrant (1994) show that China was a major contributor to the decline in yield growth after the mid-1980s, but that in India the rate of yield growth doubled, rising from an average rate of 1.6% from 1973-75 to 1981-83 to 3.2% from 1981-33 to 1988-90. Perhaps it would make sense to take a close look at the Indian experience to determine what promise it might have for increasing rice yields, not only for India but for irrigated systems elsewhere in Asia. As recently as October 1994, it was observed that eastern India, while still a relatively low-yield area, nontheless has high potential for substantial yield growth (Byerlee 1994b).

The relative India/China experience suggests a general proposition: perhaps those with research and policy responsibilities for rice ought to think of the desirability, and feasibility, of opening the rice system to more trade among countries. At present, only about 4% ot global rice production moves in international trade. There may have been good economic and environmental reasons for the slight importance of between-country trade to date. But with some important irrigated areas now bumping against seemingly intractable yield ceilings, it may make sense to think of expanded trade as an alternative to yield-increasing efforts in those areas if, as seems to be the case, the economic and environmental costs of increasing yields elsewhere would be lower. Increased research to raise irrigated yields clearly seems indicated. But greater use of the trading option might ease the research task.

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EIGHT

GATT and rice: do we have our research priorities right?

P.L. Pingali

Much has been said in recent months about GATT and its impact on developing country agriculture. Much of this discussion has been based more on perceptions than facts. Impacts of GATT have been addressed more in terms of the short term rather than the long term. What is missing in the discussion is an understanding of the long-term benetits of trade liberalization and the role of GATT in inducing long-term structural adjustments.

This paper focuses on the agricultural sector, specifically on rice, and identifies the short-term and longer-term consequences of GATT implementation. The implications of trade liberalization on rice research priorities are identified. It is argued that the short-term impact of GATT on rice production and trade could be modest. Over the long term, however, agricultural transformation and the commercialization of rice systems could lead to a substantial change in the world rice market. Asia could, over the long term, import a part of its rice requirements from other continents. Sustaining productivity growth in the irrigated lowlands and the intensification of the rainfed lowlands could reduce the magnitude of imports required.

GATT: agreement on agriculture

"The General Agreement on Tariffs and Trade—GATT—is a binding contract between 105 governments which together account for 90% of world merchandise trade. The objective of the contract is to provide a secure and predictable international trading environment for the business community and a continuing process of trade liberalization in which investment, job creation and trade can thrive. In this way, the multilateral trading system contributes to economic growth and development throughout the world" (GATT 1992).

The final agreement on multilateral trade, resulting from the Uruguay round of GATT negotiations, was signed by the contracting countries in December 1994 and went into effect on 1 January 1995. The above, legally binding agreement provides a comprehensive set of rules for the conduct of trade in agricultural commodities and for the conduct of domestic agricultural policy to the extent that it impinges on international trade. An important factor determining the effectiveness of the agreement is that it not only establishes general rules to be observed in international trade, but that all participating countries undertake specific commitments, expressed in their schedules. This section discusses the major elements of the Agreement on Agriculture and highlights the agreed upon exceptions to it. Tangermann (1994) and Josling et al (1994) provide a comprehensive discussion of the Agreement on Agriculture. FAO (1994) provides an assessment of GATT for developing country agriculture.

Commitments for agricultural reforms were made in three broad areas: market access; export competition; and domestic support. The actual mechanisms for encouraging trade flows are through reductions in tariffs, subsidized exports, and domestic price supports, and through minimum access commitments. Developing countries were treated differentially in terms of lower levels of commitments and longer periods for compliance.

The implementation of the GATT agreement starts in 1995, and the reduction commitments of the developed countries should be completed by the year 2000, whereas the commitments of the developing countries should be completed by 2004. The next round of GATT negotiations should start in 1999 and last for four years.

Market access

All participating countries have agreed to bind all tariffs, to convert all existing nontariff barriers into bound tariffs, and not to introduce new nontariff measures. For developed countries, bound tariffs have to be reduced by 36% over the 6-year implementation period (1995 to 2000), on a simple (unweighted) average basis, with a minimum rate of reduction of 15% for each tariff line. In the case of developing countries, reduction commitments are only two-thirds of those for industrialized countries and the implementation period is 10 years (2004). In the case of least developed countries, there are no reduction commitments although they also are expected to bind their policies at the base period level (1986-88). A few countries, notably Japan and the Republic of Korea, had sought and obtained special treatment with respect to rice imports, the specific features of the "rice clause" are discussed later in the paper.

In order to hasten the entry into traditionally closed markets, minimum access provisions are being implemented. Where there are no significant imports, minimum access equal to 3% of domestic consumption in 1986-88 will be established for 1995, rising to 5% of base year consumption at the end of the implementation period. In cases where current access opportunities are more than the minimum, they will be maintained during the implementation period. Importation of minimum access quantities is not guaranteed, although reduced tariff rates are provided as an incentive to fill these quotas.

Export subsidies

Subsidized exports have been brought under the purview of international regulation as part of the GATT treaty on agriculture. Countries have individually accepted legally binding commitments regarding maximum export subsidies. Exporting countries have accepted commitments leading to a reduction in expenditure on export subsidies of 36%, and reduction in the quantity of subsidized exports by 21% during the 6-year implementation period. Participating countries have also agreed not to provide export subsidies in the future for commodities that are currently not subsidized. Developing countries generally do not subsidize exports and hence are largely unaffected by the above rule.

Domestic subsidies

Domestic subsidies are measures implemented by a country to reduce the costs of production or increase the net revenues received by producers in the domestic market. Domestic subsidies come under GATT purview to the extent that they have a trade distorting effects. This is the first time that GATT has direct intervention capacity with respect to domestic agricultural policy. Agricultural policies are divided into two groups: 1) those with trade distortion effects, and 2) permitted policies—"green box policies"—those with minimum distortion effects. The first set of policies, those that lead to production beyond the economic optimum, are to be quantified and are known as the aggregate measure of support (AMS). Developed countries will reduce their AMS by 20% over a period of 6 years, starting in 1995. Developing countries are to reduce their AMS by 13% over a period of 10 years, also starting in 1995.

Green box policies, those that encourage investments in agriculture and subsidize production inputs critical to the development of agriculture in developing member countries, are exempted from reductions. Green box policies include investments in research, pest and disease control, training, extension and advisory services, inspection services, marketing and promotion, and infrastructure services.

Sanitary and phytosanitary measures

Participating countries agreed to greater transparency in rules and screening procedures for sanitary and phytosanitary measures. The idea was to make it easier to distinguish between genuine health and safety concerns and disguised protection. Countries continue to have the right to set their own health and safety standards but these are to be based on "sound scientific evidence", and international standards are to be followed to the extent possible. International standards are to be based on the guidelines provided by organizations such as: the Codex Alimentarius Commission, the International Office of Epizootics and similar bodies.

Impact of GATT on rice trade and rice prices—short and medium term

This section provides a preliminary assessment of the impact of GATT rules on rice trade. The period under consideration here is 2000 to 2004, which is the short- to medium-term response period. Additional supplies are assumed to be coming from existing capacity, without substantial investments in increasing capacity, such as adding large areas under irrigated rice production. Changes in food preferences follow current trends over this period, no dramatic deviations from the trend are anticipated. Information on country-specific negotiated positions is summarized to the extent possible.

Market access—special treatment for rice

In the short to medium term, a modest expansion in rice trade can be anticipated due to the opening up of traditionally closed rice markets, such as Japan and the Republic of Korea. However, due to a negotiated special treatment for rice the extent of market opening is not as dramatic as it might have been. During the final stages of GATT negotiations, political considerations led to the adoption of a special clause for certain commodities. Because of the importance of rice importing countries in this negotiation, it has been dubbed the "rice clause".

The special treatment given to rice is applicable to developing countries where rice is the predominant staple and to developed countries that import less than 3% of their consumption. Japan, the Republic of Korea, and the Philippines availed the "rice clause", and Indonesia negotiated a separate agreement on rice imports. The above countries are exempted from tariff reductions in exchange for minimum access quotas. For developed countries, the quotas amount to 4% rising to 8% of domestic consumption over a 6-year period. In the case of developing countries, the corresponding quota is 1-2% in the first 5 years, rising to 2-4% in the next 5 years.

Table 1 summarizes the negotiated rice imports of Japan, Republic of Korea, Philippines, and Indonesia. Since the Philippines and Indonesia are currently importing amounts equal to or greater than the negotiated levels, their settlement does not lead to additional import requirements. The Japanese and South Korean settlement, however, puts upward pressure on the rice market. Starting with imports of a little over 400,000 t in 1995, the two countries are expected to import over 1 million t by the

Table 1. Negotiated imports 1995-2004 ('000 t).

Country	1995	2000	2004
Japan	379	758	800[a]
Republic of Korea	50	100	200
Philippines	59	120	239
Indonesia	70	70	70

[a] To be renegotiated by the year 2000.

year 2004. This is a conservative estimate, however, since the rice exception for Japan will be renegotiated by the year 2000. Japanese and South Korean imports are primarily japonioca rice and will put an upward pressure on a market that is severely constained on the supply side due to unique agroclimatic requirements.

The share of japonicas in world trade is approximately 12% with the USA, Australia, and China as the main suppliers. Additional supply would have to come through displacing existing importers, domestic consumers, and/or through the expansion of area under japonicas. In the short to medium term, Japan and South Korea can outbid current importers and domestic users of japonica rice from the USA and Australia, leading to an increase in its price (USDA 1994). The US and Australian capacity to substantially expand areas under japonicas is severely limited by climatic and water constraints. China can most readily increase japonica exports and will gain from the higher prices and increased export volumes (USDA 1994). Given the high domestic demand for long grain rice in China, major area reallocation to japonicas will require high levels of long grain imports.

Long grain rice trade, which will also increase due to displaced importers ot japonicas, will be increasingly redirected to Thailand, Vietnam and possibly Myanmar. The last is the only one with significant excess capacity for medium-term expansion once producer incentives have been reestablished (Pingali and Siamwalla 1994).

Reduced tariffs and export subsidies

The European Union (EU) and the USA have both agreed to reduce their tariffs on rice by 36% by the year 2000. In the case of the USA, tariff reduction is not expected to lead to an increase in exports (USDA 1994). The effect of tariff reductions on the imports ot speciality rices, such as Basmati, needs further examination. For the EU, tariff reductions could lead to an increase in the imports of high quality rice. Table 2 indicates imports of as much as 300,000 t by the year 2004. Rice consumption in the EU during 1986-88 period was approximately 1.7 million t; anticipated exports equal 18% of baseline consumption.

Table 2. Export subsidies for rice 1995-2000.

Country	Annual quantity[a] ('000 t)		Annual outlay ('000 US$)	
	1995	2000	1995	2000
USA	272.000 (11.45)[b]	39.00 (1.64)	15,706	2369
EU	177.00 (16.46)	145.00 (13.24)	58	40
Australia	None	None		
Thailand	None	None		
Vietnam	None	None		

[a]Quantity exported with subsidy. [b]Figures in parentheses are % of subsidized exports in total exports for 1986-88.

The world rice market will not be affected significantly by the reduction in export subsides. Subsidies for rice are essentially provided by the US and the European Union. In both instances, subsidy reductions have been negotiated, but subsidized exports form a very small portion of total exports of the countries concerned.

Domestic policy—subsidies and producer support

In the case of developing countries, domestic subsidies take the form of fertilizer subsidies, and provision of certified seeds and other inputs at below market price levels. Price support mechanisms are also considered part of producer support. Where the sum total of support provided is less than 10% of the total value of production—the de minis level—reductions are not required. Most developing countries claim subsidies below the 10% level and hence the impact on production from this clause can be expected to be minimal. Developed countries have negotiated settlements on domestic support that will not lead to reductions in production (Tangermann 1994).

Rice prices and supplies

The United States Department of Agriculture (USDA) projects that rice prices will rise by 11% relative to trend estimates by the year 2000 and by 14% by the year 2005 (USDA 1994). The price increases are related to the shift in the demand for japonica rice caused by increased purchases from Japan and the Republic of Korea in the face of a relatively inelastic supply. In the short to medium term, japonica rice price rise leads also to a rise in the price of long grain rice due to increased competition for international supplies. Major increases in production are not anticipated in the short to medium term. Long-term prospects for prices and supplies depend on 1) the emergence of new rice suppliers, such as Myanmar, Latin America, etc; 2) economic incentives for sustaining current production levels in developing Asia countries; 3) changes in food preferences relative to population induced growth in rice demand; and 4) further liberalization of the rice markets in East Asia. These issues are discussed further in the next section.

Implications for trade liberalization and economic reforms on the rice sector

In this section, we take a longer term (beyond 2005) and more speculative view of the transformation of the rice sector. In order to understand long-term changes in the rice sector, it is important to recognize that 1) trade liberalization is a continuous process and does not end with the current GATT agreement; 2) GATT has direct impacts on the relative profitability of rice vs nonrice agricultural enterprises; and 3) employment generation and income growth in the nonagricultural sector clue to GATT have significant impacts on the nature and organization of agricultural production. In essence, the long-term consequences of GATT can be understood only through a holistic understanding of the interlinkages between the various sectors of the economy. The point made in this section is that increased competitiveness for production resources, both in the agricultural and nonagricultural sectors, could lead to movement away from rice self sufficiency to self reliance with imports at the margin.

Income growth in the nonagricultural sector

Over the long term, GATT implementation could lead to significant growth in the nonagricultural sector based on the principles of comparative advantage. Worldwide income growth is projected to increase by as much as US$5 trillion over 10 years (USDA 1994). While the gains are certainly not expected to be uniformly spead across the developed and developing countries, one can still anticipate significant reorientation of production and income gains in the developing countries. The Philippnes, tor example, expects GATT-related annual benefits from the agribusiness sector alone to be 1) 3.4-billion peso (around 25 pesos per US$) increase in agricultural trade earnings; 2) 60-billion peso increase gross agricultural value added; and 3) the creation of 500,000 additional jobs (DOA 1994). Gains in the agribusiness sector could be expected to be relatively smaller than the anticipated gains from increased trade opportunities in the industrial sector.

There are several implications for both the demand and supply of rice in the face of rapid growth in the nonagricultural sector. On the demand side, over the long term, one should expect a shift towards a more diversified diet that includes vegetables, meat, and dairy products. The downward shift in the demand for rice induced by income growth is tempered by continued rapid population growth. Rice supplies could be expected to be negatively affected by competing demands, from the nonrice and the nonagricultural sectors, for land, labor, and other factors of production. Several countries that are now self-sufficient in rice may find that it is more profitable to import at least part of their rice requirements in exchange for diverting production resources to more remunerative activities. The reorientation of agricultural production away from self sufficiency concerns is triggered more by the price responsiveness of individual farmers than by elaborate planning exercises performed by the state.

Realignment of land use in the high potential areas

Diversification out of rice monoculture systems is most likely to occur in the irrigated lowland environments (Pingali 1992). Crop diversification can be both in terms of permanent movement out of rice systems or in terms of seasonal diversification. Where export markets are well established, the permanent switch from irrigated rice systems to horticulture and aquaculture has been observed. The recent transition in the Central Plains of Thailand is an example. Trade lilberalization resulting from GATT could, over the long term, create an environment that would be conducive to such permanent change in enterprises, although the area under such systems would be relatively small.

Domestic income growth that results from GATT could also lead to increased diversification trends in the irrigated lowlands. The demand for vegetables and fodder crops could lead to dry season diversification, especially in peri-urban areas. Rice would continue to be the crop of choice in the wet season due to the high drainage costs of the alternatives.

Realignment of land use in unfavorable areas

In environments that are unfavorable to rice production, the response to trade liberalization could be expected to be different for the uplands as opposed to the rainfed lowlands. In the uplands, improved transport infrastracture and market access could lead to a shift away from subsistence rice production. The movement away from upland rice is well under way in much of Asia today and one can expect the current trends to accelerate with GATT. Soil conditions permitting, upland areas will tend to specialize in high value commercial production systems.

In the case of the rainfed lowlands, one ought to expect rice to predominate because the drainage requirements for growing a nonrice crop in the wet season arc too high and uneconomical. There are several changes in the organization of rainfed rice production that are to be expected with GATT. Given increasing nonfarm employment opportunities and the consequent withdrawal of labor from the agricultural sector, rainfed systems will be reorganized in order to make them competitive relative to other opportunities. The movement from subsistence to market-oriented rainfed production could follow a general pattern:

- The abandoning of the highly drought prone environments, especially in areas where the opportunities for ground water exploitation are limited;
- The shift from small subsistence farms to mechanized cultivation of large farms; and
- Where dry season water supplies are available, increased areas under vegetables, fodder legumes, and other high value crops.

With GATT the rainfed lowlands will have a comparative advantage in rise production. but given the productivity differences, the bulk of market supplies will still have to come from the irrigated environments.

Prospects for the rice market and regional re-alignments in rice production (within Asia and outside Asia)

Over the long term, the reorganization of production resources in the traditional rice-growing environments of Asia, especially the diversion of high potential lands to nonrice enterprises, could lead to a net increase in the import demand for rice in several Asian countries. Over the long term, changing comparative advantages could lead the major rice consuming countries of Asia to import at least 5% of their consumption requirements. If India, Bangladesh, and China import 5% of their baseline consumption requirements (1986-88 levels), it could lead to an increased pressure on the world rice market of approximately 8 million t (Table 3). If the other rice importing countries of Asia are included, rice import requirements could rise by an additional 2 million t. Potential import demands, in the long term (beyond 2005), could lead to an expansion in the world rice market from the current level of 14 million t to 24 million t, an increase of 70%. This additional demand is exclusive of the increased import demands due to increased population growth and degrading current productive resources, such as the degradation of irrigation infrastructure in countries that are currently self sufficient in rice.

Table 3. Potential trade access to South Asia and China ('000 t).

Country	Consumption	Imports	Potential access beyond 2005
	1986-88		
Bangladesh	14.67	0.329	0.734
India	51.59	0.242	2.579
China[a]	110.39	0.412	5.519

[a] China is not a signatory to GATT

Can the current rice exporters provide the additional 10 million t required beyond the year 2005? If not, what are the prospects for additional supplies coming from countries that are currently minor exporters but with capacity for expansion? The current, major rice suppliers are Thailand, USA, and Vietnam. Expansion of exports from these suppliers is severely constrained by agroclimatic conditions, increasing costs of expanding irrigated areas, both monetary and environmental, and increased competition for production resources devoted to rice. In Asia, rice export supplies could potentially come from Myanmar and Cambodia. Pingali and Siamwalla (1994) have argued that Myanmar could export approximately 2 million t with the existing rice infrastructure if policy reforms bring about improved production incentives for farmers. Cambodia used to export 0.5 million t of rice in the mid-1960s. This historic share of the export market could potentially be reclaimed. With added investments in irrigation and other infrastructure, long-term prospects for exports from Cambodia could go up to 1 million t.

One could assume that approximately 4·5 million t of the additional exports could come from within Asia. Even under such an optimistic scenario, approximately half the additional rice supplies would have to come from outside Asia. The only two regions with large unexploited potential are Latin-America and Africa. If there is assured demand from Asia, to the tune of 4-5 million t per year that is not expected to be met by current suppliers, investments could be made to generate those supplies. Latin America is likely to exploit its potential earlier than Africa, since it has the broader road and transport infrastructure and also 21 strong research infrastructure already in place. A more detailed analysis is required on the costs of exploiting unused capacity in Africa and Latin America. The comparative advantage of the above regions in commercial rice production also ought to be assessed.

Equity and environmental implications

Equity implications of GATT ought to be evaluated in the broader context of income distribution changes that come about due to trade liberalization. Anticipated staple food price increases resulting from GATT implmentation also raise equity concerns especially in terms of their impact on the rural and urban poor. It is not necessarily true that the benefits of GATT will accrue only to large farmers and those in environments with high potential. GATT, over the long term, could potentially lead to a reduction in income differential between the high potential and low potential environments by drawing surplus labor out of agriculture and into industrial-service sectors. The resulting increase in real agricultural wages benefits landless labor households remaining in agriculture. Given the evidence on equalization of wages across production environments (David and Otsuka 1993), there is every reason to believe rising wages benefit the high potential and low potential environments. The possible rise in real food prices could have serious consequences on poor consumers. The supply responsiveness of nontraditional rice suppliers, such as Latin America and Africa, could dampen the magnitude of the price rise.

Environmental impacts of GATT could be both positive and negative. The phytosanitary agreement discussed above provides a basis for standardizing and promoting safer pesticide use and reducing the incidence of residues on food products, especially those exported. The use of persistent pesticides could decline with greater international trade in food. In Asia, the move from monoculture rice systems in the irrigated lowlands to a more diversified production systems could have long-term productivity benefits by improving soil fertility (Cassman and Pingali 1995, Pingali 1994). Increased chemical use for high value crops and increased herbicide use as a substitute for hand weeding continue to be matters of concern both from an environmental and health point of view (Pingali and Roger 1995, Pingali et al 1995). Also, an issue that needs careful attention is the impact of intensive cultivation of high value crops in the uplands, especially in terms of soil erosion. In the case of the uplands, an assessment is required on the role of improved property rights as a means of encouraging erosion control investments (Pingali 1990).

GATT-related expansion of rice cultivation in non-Asian countries could also lead to environmental concerns, specifically in terms of water. Intensive cultivation of rice for exports would require expansion in irrigation and drainage infrastructure in Latin America and Africa. The problems with intensive irrigation water use that were encountered in Asia are relevant to these continents as they intensify rice production. Specific attention ought to be given to water-included paddy land degradation, such as salinization, soil toxicity build up, waterlogging, etc. Given the experience of Asia, it could be possible to pay greater attention to these environmental factors in the design and development of irrigation infrastructure in Africa and Latin America.

Implications for rice research priorities

Research resource allocation for irrigated vs rainfed systems

The allocation of research resources between the favorable and the fragile environments is generally based on congruence analysis, reflecting the importance of the above systems in terms of area and production. Strict congruence analysis would indicate a research resource allocation of 70% for the irrigated lowlands and 30% for the unfavorable environments. IRRI has modified the above allocations by explicitly incorporating equity concerns in the analysis, since the majority of the rural poor live in the unfavorable environments. The poverty modifier has resulted in a resource allocation of approximately 50-50 between the two broad rice environments. Given the long-term impact of GATT on the increasing competitiveness of the irrigated environments, for other crops and other nonrice enterprises, there is a need to modify the above congruence analysis. The upland environment, as discussed in the previous section, also face increasing competition due to growing commercialization. At the same time one would have to consider the productivity differences between the favorable and the unfavorable environments and the probability of research success, the latter being small for the unfavorable environments.

While a revised priority-setting exercise has yet to be conducted, one could speculate that the outcome would not be significantly different from an equal split between the favorable and unfavorable rice environments. However, within the unfavorable environments themselves, one ought to expect a significant reduction in emphasis on rice in the upland environments and on the highly drought prone rainfed environments.

Intensification versus diversification

With growing commercialization trends, the emphasis of the irrigated environments would shift from rice monoculture systems to diversified farming as discussed earlier. From a research point of view, understanding rice as part of a system in which several crop and noncrop activities occur becomes crucial. The profitability of component rice production technologies ought to be assessed within the context of a diversified farming system. The relevant measure of system performance in such a diversified system is no longer yield, but total household income and total factor productivity.

In the case of the rainfed lowlands, intensification continues to be the most important research objective, both in terms of adding crops as well as increasing yield per hectare per crop. Breeding and crop management activities designed to reduce water stress are high priority activities in the rainfed lowland system. The concentration on the uplands ought to shift from attempts to increase the productivity of the rice crop to sustainable management of a diversified production system.

Yield enhancement versus quality improvements

Even with the diversification trends irrigated lowlands will continue to the main sources of rice supply for the growing urban population.. Given the increasing diversion of some of the irrigated rice lands to nonrice activities and to nonagricultural uses, such as urban and industrial uses, it imperative to continue the high research emphasis on shifting the rice yield frontier. The new plant type, can be expected to play an important role sustaining the yield productivity growth for rice. Even as the emphasis remains on shifting out the yield frontier, increased attention ought to be paid to enhancing rice grain quality. As incomes grow in Asia the demand for higher quality rice will increase and the research system ought to be able to respond with high yielding, high quality rices.

Knowledge-intensive technologies—increased opportunity cost of labor

Increasing opportunity costs of labor due to enhanced off farm employment opportunities have significant implications for priorities in crop management research. Recent work in crop management research has concentrated on increasing input the efficiency through the use of knowledge intensive technologies, such as integrated pest management, judicious use of irrigation water and improved fertilizer management. All of the above technologies require the farmer to spend time in management, supervision, and use of the technology. Farmer time can be expected to become an increasing expensive input in farm production and hence the profitability of knowledge intensive technologies for enhancing input efficiency is brought into question. Research ought to concentrate on increasing input efficiencies while minimizing farmer time requirement.

Private sector versus public funded rice research

With the implementation of GATT and the agreement on intellectual property rights there is a growing perception that the private sector could carry out much of the needed agricultural research. While it is true that the environment of the private sector in research will increase it is unreasonable to expect that it will substantially replace public funded research. The private sector will tend to concentrate on research activities from which it can fully capture the returns to its investment. Investments in biotechnology, especially gene constructs and transgenic plant materials, and hyhrid rices are areas where the private sector can recoup its invesments. In more traditional breeding activities and in studies on understanding processes the knowledge tends to be freely available once it is generated. Because of the "public good" nature most agricultural research it will continue to be essential for the public sector to invest in it. This is particularly true for research on the less favorable environments which tends to be characterized by longer gestation periods and lower prob ability of success.

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National Perspectives

NINE

The medium-term agricultural development plan and sustainable agriculture

R.S. Sebastian

We are honored that the 1995 International Rice Research Conference is held here in the Philippines. We look forward to a productive and enlightening dialogue as we interact and exchange views on how to address the challenge of improving the quality of fragile lives in an increasingly fragile environment.

Our vision of Philippines 2000: empowering the countryside

The Medium-Term Philippine Development Plan (MTPDP) for 1993-98 is our blueprint for achieving industrialization by the 21st century Our pursuit of sustainable development and the empowerment of the Filipino is clearly defined in our vision of Philippines 2000. It is our goal that the turn of the century will see our nation politically, economically, and socially secure, peopled by a citizenry who are masters of their lives and guardians of their children's future.

Inspired by this vision, the agriculture sector has taken up the challenge of transforming the countryside into a vibrant, productive, and dynamic engine of growth and development while ensuring the judicious use of our finite resources. The Medium-Term Agricultural Development Plan (MTADP) within the MTPDP is to accomplish the following:

- To rationalize the use of our agricultural resources by providing farmers with options for making the best use of their lands and obtaining the best returns on their investments. It confronts the task of increasing productivity while preserving the fragile balance of our ecology.
- To empower our farmers and our fisherfolk by giving them better access to the skills, technology, and markets needed to make agriculture more competitive and profitable.

The KPA approach: the best use of our lands

To make more productive and competitive, the Plan adopts the Key Production Area or KPA approach. Specific agricultural products are matched with the best agro-climatic features that maximize yields, and where market conditions are favorable for producing, processing, and marketing these goods. Simply, put, it means planting the right crop, at the right place at the right time. This will enable farmers to progress beyond traditional rice culture and diversity agricultural production. For example, we have at present some 2.5 million ha planted to rice and another 2.5 million planted to maize. We envision that the rice and maize production will soon be concentrated on only 1.9 million ha identified as best suited for these crops. Even as rice and maize areas are reduced, we will still be able to maintain self-sufficiency in these crops as yields continue to increase.

In 1994 alone, rice paddy production increased by 11.7% to 10.5 million t. Our target is to increase paddy production in the KPAs to 12 million t by 1998. The remaining 3.1 million ha freed up would then be diversified to forage production to support our livestock development and commercial export crops in which we have a comparative advantage. This also offers our farmers larger incomes and better lives for themselves and their families.

At present, the Department of Agriculture is implementing four major programs nationwide using the KPA approach. These are the Grains Production Enhancement Program, The Medium-Term Livestock Development Program, the Key Commercial Crops Development Program, and the Medium-Term Fisheries Management Program. At the heart of the MTADP is the provision of vital infrastracture consisting of irrigation system, farm-to-market roads, post-harvest facilities as well as research and development programs and marketing assistance. Thus, the MTADP is an integrated blueprint to spur increased farm productivity and sustainable rural agri-industrialization. For 1995 alone, some P18 billion ($US720 million) from the national coffers were allocated to fund the MTADP.

Kalikasan: the Philippine IPM experience

Even as we work to provide a strong agricultural base to support our bid for industrialization, we have always championed the cause of protecting and preserving our environment, as well as the welfare of our farmers. One example of our effort in this area is KALIKASAN, which is our National Integrated Pest Management Program, launched in May 1993 by President Ramos. IPM is quickly gaining ground among our farmers as a standard, inexpensive approach to crop husbandry and pest management in major rice, maize, and vegetable growing areas in the Philippines.

Today, we have some 17,300 rice farmers trained under KALIKASAN and practicing IPM on their farms. At the same time, IPM farmers have become leaders in their own communities, managing their farms and their livelihood. Government continues to provide a policy environment where IPM can thrive. Local government units are also actively engaged in partnerships with IPM communities, by providing counterpart funds for training and research. Thus, IPM is fast becoming a viable earth-friendly alternative to hazardous methods of farming.

Policy and research: a partnership

The success of IPM in the Philippines is anchored in the symbiotic partnership between policy and research. IPM is in reality a process that enables farmers and extension workers, working together, to evolve practical solutions to crop management problems unique to their farms. IPM brings technology to the grassroots, and at the same time is enhanced by the knowledge that our farmers have gained from working closely with the land. In this way, research becomes responsive to the needs of farmers because it reflects the true state of agriculture in their locales as they know it to be. Crop protection policy, on the other hand, has provided the impetus to realize our quest for sustainable growth in the countryside.

Indeed, we see in this kind of dynamic synergy between policy and research a potent lever for accelerating sustainable development. It is therefore encouraging that this Conference is being conducted precisely to strengthen and enhance this partnership. Policy measures must enhance and sustain the achievements of research and vice-versa, so that we may realize our vision of rural growth. Both serve a common purpose—that of uplifting the quality of human lives in less fragile environments.

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TEN

Philippine agricultural research and policy into the 21st century

C.F. Habito

It is a great honor to be part of this all-important International Rice Research Conference. Let me theretore thank the organizers, Director General Klaus Lampe, in particular, for inviting me to speak on a topic that is, as you know, very close to my heart, myself having been involved in the past in so many activities related to agricultural policy. By the way, let me assure you that, owing to the nature of my present responsibilities, I still am closely following developments in the sector, and therefore still excited to learn from, as well as to contribute my own insights to, this conference.

"Fragile Lives in Fragile Environments: Priorities, Policies and Research in Less-Favorable Rice Ecosystems", I thought, seemed a little too pessimistic for a conference theme. I recognize, however, that this does not make it a less-than-accurate description, for what we see in the fields is indeed still far from the ideal.

Director General Klaus Lampe could not have said it more accurately when he pointed out the need for policy-makers, planners, and scientists to get together more often. Indeed, only through a constant interface and exchange of observations can we be able to mutually respond to one another's concerns. That way, we are also assured that the general welfare—not just the agricultural sector—can be best served.

I understand that for this, during the second part of the conference, we are expected to give some insights on the topic "Linking agricultural research and policy." As a starting point, I would like to dwell on the prevailing agricultural scenario, then proceed to a discussion of the key government strategies and policies to address its concerns. I will also give my views on how these can be interwoven with advances in agricultural research.

The agricultural sector

The agriculture sector has always played a critical role in the Philippine economy. From 1987 to 1992, the sector has, on average, contributed one-fifth of the total gross domestic product. More significantly, it has employed almost half of the country's labor force.

Agricultural growth, however, has remained relatively slow compared to those of the other major economic sectors, especially in the most recent periods. Some salient aspects of the policy regime tended to prevent agricultural production from responding fully to price incentives. Moreover, inadequate investments in critical support services like research and extension, irrigation, postharvest facilities, and farm-to)-market roads have contributed to the slow growth in agricultural productivity.

We can trace the generally weak performance of the sector to its poor linkages with the rest of the economy. Past development initiatives treated agriculture and industry as though they were two separate, water-tight compartments. Consequently, they have failed to bring about the needed structural changes necessary for both sectors to achieve their full potentials in fueling economic growth.

We, of course, have come to realize that this approach only served to reinforce an agriculture sector that is focused on the production of primary products; and an industrial sector dominated by import-dependent manufacturing and processing industries. This has admittedly entailed a waste in government resources in view of either competing, conflicting, or duplicative efforts, with no real growth and development accruing to the economy.

The Medium-Term Philippine Development Plan (MTPDP) for 1993-98 recognizes the long-neglected need to simultaneously carry out reforms in the agriculture and industry sectors in order to improve the country's domestic production. It therefore advocates—perhaps for the first time in Philippine planning history—an area-focused, agri-industrial development (AID) strategy that aims to strengthen the links between these two major engines of growth.

The strategy aims to develop a highly productive agricultural sector built upon viable farm enterprises with strong production and marketing linkages with industry. At the same time, it aims to develop a strong and competitive manufacturing sector that uses local materials and creates new employment opportunities.

The gains achieved from ensuring economic activities are then seen as an opportunity for attaining a more equitable distribution of income and wealth among the population. Through improvements in income and productivity, we hope to raise human and physical capital as well, and thus, enable them to contribute to the general upliftment in the lives of small entrepreneurs, farmers, fisherfolk, and rural workers.

Major goals and features of the agri-industrial development strategy

Anchored on the twin strategies of people empowerment and international competitiveness, the agri-industrial development strategy specifically trains its sights on the following major goals:

- Industrial restructuring for worldwide competitiveness and expanded production of goods and services for the domestic and export markets;
- Strong, productive, and ecologically sound links between agriculture and industry;
- Increasing incomes, productivity and access to resources among small entrepreneurs, farmers, and fisherfolk.

Achieving these goals necessarily demands the modernization of the production sectors. For instance, technology must be upgraded; information technology, in particular, must keep a breast with the demands of all sectors. Rural industrialization, including the dispersal of industries to regions outside of Metro Manila, must be stepped up. Similarly, the country's natural resource base must be rehabilitated and assured of sustainable use. The agrarian reform sector must be sped up together with other initiatives to empower workers and employers alike as partners in the development process. Lastly, tourism must be aggressively developed into a major contributor to regional economic development.

The spatial orientation of the strategy arises out of the need to prioritize the development of specific areas, given the government's limited resources. Regional growth centers (RGCs), hence, are being established to serve as total points of development, where growth can easily be sparked, and from where it could start spreading across the country's 14 regions.

The development of RCGs, however, is premised on the availability of raw or semi-processed agricultural products, which will serve as inputs to agricultural processing activities. An area-focused approach is therefore similarly carried out for the sector, with a view to attaining an optimal production of agricultural commodities and promoting the growth of agribusiness.

To complement the spatial orientation of the AID strategy, identified priority commodities and industries are being promoted by the government. Agricultural goods deemed as having strong competitive potential include animal feed ingredients, cut flowers, livestock and poultry, fresh and processed fruits and vegetables, and fishery and marine products. At the same time, the government continues to support the production of basic commodities like rice, maize, sugar, and coconut in view of their strategic importance to agri-industrial development.

Government support for these selected products is largely institutional in nature. This includes the provision of production and postharvest facilities, market development assistance, and capability-building or organization strengthening for entrepreneurs, farmers, and fisherfolk.

For the 1993-98 period, gross value added (GVA) in the agriculture, fishery, and forestry sectors is targeted to grow annually at an average of 2.7 to 3.4%. By 1998, we expect to achieve self-sufficiency in rice at a level of 10 million t. For maize, we are aiming for an annual average growth of 5.6%—enough for us to ensure self-sufficiency in animal feed requirements. Livestock and poultry production will grow at an annual average rate of 4.2 to 5 and 4.4 to 5.1%, respectively, while fisheries will grow by 1.6%, on average.

Government policy initiatives in support of agriculture

Given the specific targets outlined for the sector, the government's policy initiatives revolve around four major areas of concern: 1) improving farm productivity, 2) ensuring food security, 3) enhancing competitiveness, and 4) promoting sustainable farm productivity, ensuring food security, enhancing competitiveness, and promoting sustainable agricultural management practices.

Our ability to sustain production to meet our growing food requirements depends, to a large extent, on how we use and manage our land and water resources. Recognizing the need to promote the best use of land, the Plan supports the development of key production areas (KPAs) for rice, maize, livestock, fisheries, and specific commercial crops in regions that have the comparative advantage in producing these commodities. Through this approach, the government would find it easier to remove the bottlenecks that impede the competitiveness of key commodities. It also ensures efficient use of scarce resources and helps farmers and fisherfolk obtain the best returns on their investments.

Using the KPA approach, some 1.2 million ha for rice and about 700,000 for maize have been identified as KGAs. These KGAs will be the focus of government support for the rice and maize subsectors. Through this initiative, a seed development program will be implemented to ensure the availability of quality stock seeds. This will enable farmers to increase their productivity and, on the whole, ensure increased production in both rice and maize.

In addition, required basic infrastructure and service shall be provided in the rural areas to assist small farming and fishing families and sustain their productivity. We can, therefore, expect greater resources being poured into the provision of irrigation and drainage, farm-to-market roads, and postharvest facilities.

The effort to enhance productivity and hike the total production of goods and services would undoubtedly require substantial investments in agricultural research and development. The government, therefore, stands four-square behind—in fact actively supports—the conduct of basic research and technology generation on priority commodities identified under the Plan. Priority areas for research include the development of new varieties, production and related technologies, postharvest technologies, and the development of appropriate farm mechanization technologies.

The need to enhance the competitiveness of agricultural commodities assumes an even greater importance in the light ot our participation in the General Agreement on Tariffs and Trade—Uruguay Round (GATT-UR) and the establishment d the World Trade Organization (WTO). In seeking a favorable macroeconomic environment, the government has committed to reduce its intervention in the production, marketing, and processing of agricultural and industrial inputs and outputs. This will be accomplished through the avoiding price controls, export taxes and levies, as well as the abolition and avoidance of production controls and other mechanisms that restrict competition in agribusiness.

These reforms are expected to encourage more private investments in agri-based enterprises. In line with the import liberalization program, the government supports the reduction of tariff rates on agricultural inputs and machinery in order to lower tariff costs.

In our campaign for increased production, we shall, however, remain faithful to the principles of sustainable development. Sustainable agri-industrial development unquestionably requires the adoption of policies designed to protect the environment and rationalize the use of scarce resources.

It is easy to see, therefore, why we encourage the use of organic fertilizers, biological pest control, and other environmentally sound management techniques to increase land productivity. Apart from these, we promote the implementation and integrated pest management program and have taken positive steps to stop the use of pesticides already banned in other countries.

Recognizing the many competing and often conflicting uses of land for agriculture and industry, a national land use policy is being developed that is consistent with agrarian reform objectives and the need to ensure the best use of land resources. The matter of land conversions, therefore, has to be closely looked into, having in mind the needs of both economic development and resource conservation.

Role of agricultural research in agri-industrial development

The heavy emphasis on improved productivity and enhanced competitiveness in the agriculture sector necessarily entails intensified agricultural research and development activities.

To ensure that R&D initiatives appropriately address the requirements of agri-industrial development, we are encouraging a stronger and more active partnership between the government and the private and nongovernment sectors in the development of R&D programs, particularly those geared toward the development of new, improved and value-added products with domestic and export potential.

Aside from acquiring and adopting appropriate production and processing technologies, research institutions are enjoined to participate in the implementation of a massive and aggressive technology and transfer and commercialization program focusing on productivity-enhancing technologies. This includes the conduct of support programs to accelerate technology transfer through the provision of information, marketing, training, and financing support services.

For its part, the government is putting a premium on the upgrading of science and technology (S&T) services and facilities needed in the production and processing of priority commodities and industries. Our S&T network is being strengthened for the effective and efficient implementation of S&T programs through better facilities and manpower.

To encourage the growth of technology-based industries, S&T manpower capability shall be developed and upgraded by strengthening engineering science education and by providing relevant technical training. Along these lines, we are pushing for the prompt implementation of the Scientific Career System. We are hopeful that through better incentives and compensation schemes, we will be able to encourage outstanding scientists and technologists to engage in the scientific work so vital in making our agriculture world-competitive.

Conclusions

In general, what we undertake to achieve by 1998, the end of the Plan period, is a highly productive agricultural base that is systematically linked with industry and manufacturing. At the same time, we envision our country as having attained self-sufficiency in at least some of its staple requirements, while producing quality commodities that can satisfy both domestic and international standards. With these having been accomplished, there is no reason to doubt the emergence of a productive and vibrant agri-industrial sector that will be our springboard toward a newly industrialized country status by the year 2000.

But as we have emphasized time and again, all of us—the government, the academe, NGOs and POs, and other organizations making up the private sector—have a stake in this envisioned transformation. We all have roles to play; we all have responsibilities to assume.

In closing, therefore, I wish to echo the call made by the organizers for agricultural scientists, planners, and policymakers alike who influence to a large extent the future directions of agricultural development, to transcend the lines separating them and achieve unity in addressing the sector's diverse concerns. 1 believe that this conference will contribute significantly to getting us physically and mentally together. What we wish to see later on, however, is complete harmony in moving and getting our acts together.

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ELEVEN

Policy areas in rice research and key technological interventions in India

S.J. Das

The Asia and Pacific region has 30% of the global agricultural land spread over 30 countries ranging from Iran-Pakistan in the west, Japan in the east, China-Mongolia in the north, and Australia-New Zealand-Pacific Islands in the south. This region sustains a population of about three billion and accounts for more than half (56%) of the world's population. Nearly 73% of the world's farming households are in the Asia–Pacific Region. At the present growth rate of 1.8%, the human population is expected to reach 4.1 billion by 2010.

The Asia-Pacific region has been in forefront of generation and transfer of modern technology and consequently achieved agricultural production growth rate of about 4% during the past two decades. High-yielding varieties of rice and wheat have more than doubled the production of these crops since 1970. The region produced 480 million t of rice and 215 million t of wheat during 1997. The resilience and the creativity of the farmers, supported by agricultural research, have helped South Asia to shed its "basket case" stigma.

However, the gains were associated with some negative impacts. Land, water. and even climatic degradation are now major constraints to crop intensification. The production resource base has been both shrinking and degrading under pressure of increasing population and development needs. Productivity in some major agro-ecological zones has ceased to increase; in others it has declined, raising concerns about the long-term sustainability of such systems. Sustainability threats also arise from increased genetic vulnerability and incidence of insect pests, diseases, and weeds.

Today, the Asia-Pacific region has about 400 million undernourished people. It is projected that, in the near future, Asia will be needing additional 185 million t of rice and 76 million t of wheat, annually. The region will need to import 44.4 million t of rice, which would be about 11.5 million t higher than present import figures. The situation for coarse grains, too, will be adversely affected unless measures are adopted to improve further the level of productivity. Given the projected population growth rate, the pace of increase in production will have to accelerate to prevent the misery of future hunger.

The above facts and the changing world scenario demand a critical look at the current priorities and policies related to agricultural research and development. It is, therefore, imperative to evolve strategies to meet successfully the future challenges. The following thoughts are in this regard.

Agricultural policy in retrospect: India

In India, agricultural policy in the 1950s concentrated on fundamental social reforms such as removal of landlords, moneylenders, and middlemen to curtail the exploitation of the farmers. These were directed towards liberating the peasants from economic strangleholds and to improve the incentive structure of Indian agriculture. The foundation of modern agriculture by way of investments in irrigation and fertilizer was laid. Agricultural production rose sharply as compared to the pre-independence period, but the escalation of population growth resulted in more problems for rural peasantry.

The early 1960s saw agriculture fall victim to the vagaries of nature and food grains had to be imported in large quantities. This phase was probably a blessing in disguise as amid such trying situations a new agricultural strategy evolved. This program centered around the HYV seed-fertilizer-irrigation-plant protection technology. The integration of the technologies resulted in a record harvest of about 108 million t of foodgrains by the 1970-71 period. For the first time, an element of stability and self-reliance was established in food production. Even with the worst drought of the century, a shortfall of only about 20 million t was easily met by stocks accumulated during the preceding normal years. All these developments instilled much needed confidence in the minds of the farmers, policymakers, and agricultural scientists.

The decade of the 1970s, in general, saw strengthening of the research activities and dryland and rainfed areas started receiving more attention. Simultaneously, programs on rural employment generation and poverty amelioration were started.

During the 1980s, India tried to bridge the research gap by strengthening research for pulses and oilseeds, integrated pest management, natural resources, etc. The process of rural deployment through various Integrated Rural Development Programs (IRDP) continued to spread and reach the small and marginal farmers, agricultural laborers, rural artisans, weaker sections of the society, and even rural women. The results were encouraging and the absolute poverty level started declining steadily.

The 1990s have brought into focus the essential requirement of ensuring sustainability of production as well as the need to take our technologies to remote areas. Globalization of markets introduced quality consciousness and transformed a one-dimensional, production-only "mentality" to consumption demands. Research directed at systems—and mindful of processing, value addition, diversified product developments, etc.—has started receiving much-needed attention.

The coming decades will witness a new phase where our agriculture will face challenging situations on the ecological, global climatic, economic, equity, energy, and employment fronts. Obviously, the situation calls for serious introspection, particularly on the part of agricultural scientists, especially to assess their performance in the past and to set the future research agenda.

Therefore, as a strategy, it has been decided that future programs should ensure sustainability of the production system and also aim at developing technologies to:

- Suit highly diverse biophysical and socioeconomic conditions;
- Explore alternative or nonconventional plant resources for diversfication of agriculture—enhance food, fodder, fuel, and fiber production to provide the much desired food and nutritional security in the region;
- Povide technologies that are suitable, economically viable, acceptable to the regional farming community, eco-friendly, and aimed at conservation of natural resources particularly soil, water, environment, and fossil fuels;
- Enhance incorporation of bio-fertilizers in crop production;
- Enhance use of biodegradable chemicals in agriculture;
- Strengthen the production base by harnessing modern scientific knowledge and translating it to high yielding, disease-, pests, and other abiotic stress-resistant plant varieties that also have high input use efficiency;
- Generate employment for the rural poor and the landless;
- Strengthen research in social sciences to provide a realistic assessment of technology and to improve our understanding of agricultural deployment;
- Develop suitable long-duration storage and transportation techniques for grains and perishble commodities;
- Develop energy-efficient systems.

Riceproduction—challengesandstrategies

India's paddy production in 1995 is expected to reach a peak of 119 million t (about 80 million t of rice). Though the production growth is not of the desired level, with more than 20 million t in reserve, the country is able to remain selt-sufficient.

At the present level of population growth, the country, however, would be required to add annually no less than 2.5 million t of milled rice to sustain the present level of self-sufficiency. If the growth trend of the recent years is any indication, it will not be an easy task to achieve the targeted production of 95 to 100 million t from the present level of 80 million t in the next 6 years. With practically no potential for bringing more areas under rice, vertical yield improvement at no less than 3% annual growth is the only option to achieve the production targets of the coming decades.

The plateauing of yield at different levels since the late 1980s and no significant genetic yield improvement achieved since the introduction of high yielding varieties like Jaya and IR8, is indicative of the kind of challenge breeders face in tailoring varieties with higher and stable yields. In addition, genetic and physiological limitations that restrict the level of upward yield growth, the increasingly complex pest-disease syndrome, and above all the potential loss of genetic variability are causing great concern among scientists.

The permanency of the food production base on which India relies, now and for the years to come, depends on the careful utilization and production of its rich genetic diversity through organized breeding research and on husbandry of the natural resource base involving soil, water, and biology. Continued genetic enhancement for high yield and stability, evaluation of the long-term effects of intensive cropping in our ricefields, mitigation and minimization of the farmers' risks through characterizing and streamlining the resource use pattern, and arresting the pace of resource degradation and environmental pollution are required for ensuring sustainable production growth.

In this context, strategies must be developed to meet short-, medium- and long-term rice needs as broadly indicated below.

Short-term

- Consolidation of the yield gains already achieved in the irrigated ecology;
- Improvement of the yield levels in rainfed ecosystems;
- Breaking the yield barrier in high productivity areas by development and use of hybrid rice technology;
- Development of high yielding value-added varieties for export and by-product utilization;
- Ensuring reasonably high farm return through introduction of cost-effective nutrient, water, and pest management practices.

Medium- and long-term

- Raising further the genetic yield potential by plant type improvement;
- Augmentation of heterosis by two- and one-line breeding approaches;
- Exploitation of novel genes in the management of biotic and abiotic stresses through biotechnology and genetic engineering;

- Strategic and anticipatory research to conceive and evolve future varieties under various global climate change scenarios.

Policy issues

While research is a necessary precondition to reacting to the demand for significant, yet sustainable productivity increases, it is not sufficient in and of itself. There must be in place favorable policy issues crucial to sustained food production. These include the following.

Sustainable advances in the critical ecosystems

Rainfed conditions account for the largest areas (56%) under rice. The observation that the "Green Revolution" had bypassed the "rainfed ecosystems" still holds true, as no approachable production or productivity advance has been made to date. This argues for accelerated efforts at the national and international levels targeted to these ecosystems. As for India, improvement of rainfed rice with special reference to Eastern India, where 80% of the area is under diverse rainfed ecosystems is one hope for sustaining the expected production growth in the coming decades. India has taken the following steps to enhance the production-productivity levels.

- Programs to exploit groundwater during post-rainy season in regions where rainfall is high enough for crop intensification.
- Programs for effective rainwater management in drought-prone low and moderate rainfall areas.
- Compact block frontline demonstrations for exposing the farmers in rainfed areas to improved varietal and crop management technologies.
- Intensive research towards development of an ideal technology package for diverse rainfed environments through national programs and mternational research networks in collaboration with IRRI (e.g., Rainfed Lowland and Upland Consortium Programs). Establishment of problem-specific regional centers of IRRI would greatly help to find speedy solutions to the problems of ecologically handicapped rice environments.
- Special efforts to production and supply of quality seeds of varieties ot rainfed ecosystems.

Besides the above measures, there is still a need for supporting production-oriented programs in eastern India through enhanced credit facilities, increased input supply, crop insurance, etc. Special projects to improve on-farm and off-farm employment opportunities should receive priority attention.

Strengthening of public agricultural policies at national and international levels

With the World Trade Agreement and trade-related intellectual property rights having come into effect since 1 January 1995, besides promised positive gains, the age-old tradition of developing and sharing technologies, knowledge, and skill for the public good is to be replaced by private profit-motivated secrecy, competition, and possessiveness. In this new environment, improvement of self-pollinated rice and wheat—the staple food crops for the entire world—crops adapted to fragile environments and those of minor importance but vital for the underprivileged will receive less research emphasis because proprietary rights are difficult to protect, not to mention a lower return on investment compared to other agricultural endeavors. Significant to developing countries, including India, more than 70% of the food base is rice and wheat. Any lapse in sustaining the present desired minimum growth of 3.0% would lead to their dependence again on imported food. The recent prediction of Laster Brown and Hal Kane that, if India fails to sustain its present level of production growth in food, it will have to import 40-45 million t of foodgrains by 2030. This is alarming. All research and developmental efforts that have gone into attaining self-sufficiency in food will, therefore, have to be continued, if poverty and hunger are to be reduced.

In this endeavor, besides the efforts at the national level, international institutions like IRRI and the International Maize and Wheat Improvement Center (CIMMYT) should play their roles as in the past. Without their materials, knowledge, and support during the last 35 years, the national research programs could not have developed to today's level that ably caters to the country's needs. Most useful and productive programs like the International Network for Genetic Evaluation of Rice (INGER) at IRRI, which facilitates the free flow of germplasm and elite breeding lines among countries, should be further strengthened and continued.

Even in frontier areas of research such as biotechnology, the international institutions could form international/regional consortia for developing and sharing genetically engineered plants among the national institutions for crop improvement.

Collection/conservation and exchange of rice germplasm

Of more than 4 million accessions of germplasm of all crop plants available in the world today, about 0.5 million are in international genebanks. As for rice, about 80,000 accessions are available at IRRI (about 20,000 are from India). In view of the existing agreement on how germplasm in the international genebanks would be conserved and utilized under the auspices of the FAO, and how, in the future, collection and transfer of germplasm will be done following the guidelines of the FAO, we suggest the following:

- Continued and unrestricted exchange of rice-germplasm for research purposes.
- Conservation of a duplicate set of *indica* rice in an Asian country, which is rich in rice genetic diversity and possesses technical capability to conserve. (India has duplicate sets of global germplasm of pigeonpea and lentil provided by International Crops Research Institute for the Semi-Arid Tropics and the International Center for Agricultural Research in the Dry Areas, respectively).
- Collection of landraces and wild species of rice in still unexplored/under explored areas as per the code of conduct of FAO that protects the sovereign rights of the country concerned.

Increased support for development of research capability of NARSs

Since their inception, the international institutes have been playing a major role in strengthening the research capability of the NARSs, besides providing technology support. Largely through postdoctoral fellowships and short-term training programs on various subjects relating to rice, IRRI has been contributing to our human resource development in the field of rice research. In the coming years, countries like India would like to have their scientists exposed more and more to frontier areas of research through postdoctoral and visiting programs. The research topics of mutual interest could be jointly decided in biennial workplan meetings. More slots for such programs and short-term training programs would greatly help develop our research capability in advanced areas.

Notes

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Synthesis

TWELVE

Policy requirements for increasing research impact: a research perspective

R.S. Zeigler

Throughout the week-long International Rice Research Conference, there were numerous opportunities for the participants to express their views on the policies required tor enhanced research impact, including discussions and presentations around the plenary and scientific sessions, synthesis of research outputs, and formal interactions within the specific research-policy sessions. This chapter synthesizes, from the perspective of researchers, the principal points that emerged during the week. The synthesis is divided into 1) a set of overall policies that should be implemented to insure the effectiveness of research in general, and 2) policies that are specific to an area where participants believe research offers potential for significant breakthroughs.

General policy tools to increase research impact

The challenge to increase sustainable productivity in rainfed ricelands will require overcoming complex problems. The development of stress tolerant, resource-use efficient cultivars and managing the resource base will demand a highly sophisticated research undertaking. Reversing the productivity decline and increasing the yield potential in irrigated systems will demand cutting edge research as well. Therefore, a fundamental policy that must be put in place, regardless of the crop or ecosystem, is

- *Up-to-date advanced (university) educational and skill enhancement (mid-career) opportunities for NARS scientists.*

Earlier research advances were made with relatively isolated efforts. For example, the first high-yielding modern cultivars were developed largely by plant breeders. However, now and in the future, overcoming complex constraints will require a diverse mix of scientific disciplines working in harmony. Therefore, agricultural research institutions must develop and sustain

- *Institutional management and reward mechanisms to support and foster multidisciplinary research.*

The complexity of future research demands and the long-term nature of conducting research to assure sustainable increases in productivity require continuity of research, particularly at the highest skill levels. The short-term products of this research are likely to provide little profit, will broadly benetit society, should be considered a "public good", and thus should remain in the public sector. Therefore, to retain the highest caliber scientists, governments must develop

- *Attractive salary structures for public agricultural research employees that are competitive with the private sector.*

The transfer of seed-based technologies, such as modern rice cultivars, is a relatively straight-forward task. The seeds of modern cultivars simply replace those of traditional cultivars, with most tasks remaining the same. However, for maintaining the sustainability of the resource base and managing pests, for example, a complex decision-making process and understanding of some basic natural relationships will be required. To accomplish this, governments will have to develop a new technology transfer paradigm through the adoption of

- *Effective knowledge-based systems appropriate for resource-poor farmers, especially those in heterogeneous environments.*

Farmers in rainfed environments are typically very poor, with little access to credit. If they are to adopt new cultivars and practices to enhance the productivity and sustainability of their system, they must have the financial resources to do so. Therefore, governments must assure

- *Availability of affordable, adequate, and timely credit*.

Research and policy tools required for impact in rainfed ecosystems

Background

Selected scientific outputs of the Conference are summarized on pages 140-147. These are grouped into eight broad themes and placed within a "research context":

- Adapted, high-yielding rice cultivars;
- Sustainable and efficient use of nutrients;
- Water use efficiency;
- Expansion of soil volume available to crop roots;
- Direct seeded rice-driven transition from single to multiple cropping;
- Integrated pest and disease management;
- Regional crop management predictions; and
- Export-quality rices.

These themes are not meant to be exhaustive, but do highlight the most exciting and promising areas of research for the rainfed rice-growing ecosystems. The impact of the scientific outtput is indicated in terms of eight broad policy targets:

1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less-favored lands;
2) Reduction of rural poverty and increased farmer incomes;
3) Reduced labor demands for rice cultivation with labor released for other, more productive endeavors;
4) Ricelands freed for other uses as remaining lands become more productive;
5) Water resources freed for nonagricultural uses;
6) Stimulation and development of rural economies and released pressure for urban migration;
7) Reduced upland and lowland degradation and related downstream effects and
8) Preservation/enhancement of “environmental health”.

Conference participants highlighted various ongoing and future reseach areas that must be addressed to realize the impacts suggested for each theme. Finally, policy tools that most likely will be needed are identified for each theme.

Technology/output: **Adapted, high-yielding rice cultivars**

Research context

Productive and reliable cultivars are the foundation for Increasing sustainable productivity. In rainfed systems, high-yielding cultivars must tolerate the most commonly encountered stresses-drought and flooding—and capture nutrients and water efficiently from the soil. With cultivars able to tolerate stresses, recover quickly, and still produce a good yield, resource-poor farmers can afford to invest in fertility-enhancing practices. Early maturing and weed-competitive cultivars allow for different crop establishment alternatives and open a possibility for pre- or post-rice crops, providing more options for farmers and increasing cropping system flexibility. Drought and submergence tolerances are complex traits that must be understood at physiological and genetic levels to be efficiently introduced into new cultivars. Cultivar uniformity, the standard for uniform irrigated environments, may not be the best for variable environments. This calls for innovative varietal improvement and deployment schemes that Include farmers in the breeding process. The results of biotechnology research involving food crops must remain in the public domain, while breeders should be assured of appropriate recognition for their efforts.

Potential impacts[a]	Required for Impact	
	Research	Policy tools
1 **2** 3 **4** 5 **6** 7 8	• Understandingofgenotypex environment interactions; • Genetics and physiology of tolerance to drought and submergence; • Genetics of resistance to insects and diseases; • Crop growth simulation models predicting contribution of different pant architectures and performance over ranges of environments; • Incorporation of weed competitive traits, and assessment of trade-offs with yield; • Methodology for farmer participation in varietal development.	• Investments in high quality breeding and biotechnology facilities and staffing; • Support for farmer-participatory research and effective NGO-NARS linkages; • Investments in computing facilities and computer sciences education for agricultural sciences; • Cultivar/seed, intellectual property rights, and biosafety policies tailored to variable environments.

[a] Impacts. **1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less-favored lands; 2) Reduction of rural poverty and increased farmer incomes;** 3) Reduced labor demands for rice cultivation with labor released for other, more productive endeavors; **4) Ricelands freed for other uses as remaining lands become more productive;** 5) Water resources freed for nonagricultural uses: **6) Stimulation and development of rural economies and released pressure for urban migration;** 7) Reduced upland and lowland degradation and related downstream effects; and 8) Preservation/enhancement of “environmental health”.

Technology/output: **Sustainable and efficient use of nutrients**

Research context

Rice and other crops in rainfed systems often suffer from shortages of critical nutrients such as nitrogen and phosphorus. While there may be ample nutrient supplies in the soil, they may be available at the wrong time, out of reach of plant roots, lost in runoff, or pass into the atmosphere or groundwater, Where losses are high, groundwater used for drinking can become contaminated with toxic nitrates. Crop establishment and tillage practices that make more of the nutrient supply available, combined with plants that are better able to colonize the soil and take up nutrients, can greatly increase system productivity. Better plant nutrition can also reduce losses due to drought and flooding. New polymer-coated controlled or "smart" fertilizers that can release nutrients when needed, if available at low prices, can allow even poor farmers to provide adequate nutrients for their crops throughout the growing season. Diversified cropping systems can capture more nutrients and make them available for soil-enriching and allow for the production of profitable legume crops that favor subsequent rice crops as well. In even the harshest soils, there is evidence that some rice cultivars can help to improve soil quality, if managed properly, and over the long-term Increase farmers' options.

Potential Impacts[a]	Required for Impact: Research	Required for Impact: Policy tools
1 **2** 3 **4** **5** 6 **7** **8**	• Root x soil chemistry interactions for phosphorus uptake; • Nitrogen transformation processes under variable moisture regimes; • Interaction of soil microorganisms with rice roots under variable moisture regimes; • Plant growth models that simulate nutrient supply capacity and the effect on whole system productivity; • Efficiency of controlled release fertilizers under rainfed systems; • Effect of constant nutrient supply on rice's tolerance to stresses; • Effect of multi-purpose legumes on long-term soil fertility.	• Investment in state-of-the-art soil physics, chemistry, and microbiology laboratories; • Investment in the manufacturing of controlled-release fertilizer; • Fertilizer import and credit policies encouraging judicious use of "smart" fertilizers and appropriate, cost-effective formulations.

[a] Impacts: **1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less. favored lands: 2) Reduction of rural poverty and increased farmer incomes;** 3) Reduced labor demands for rice cultivation with labor released for other, more productive endeavors; **4) Ricelands freed for other uses as remaining lands become more productive: 5) Water resources freed for nonagricultural uses;** 6) Stimulation and development of rural economies and released pressure for urban migration; **7) Reduced upland and lowland degradation and related downstream effects: and 8) Preservation/enhancement of "environmental health".**

Technology/output: **Water use efficiency**

Research context

Losses to drought are a fact of life for most rainfed rice farmers. But the amount of rainfall over a season is almost always enough to support a good rice crop; It is simply poorly distributed or not available to the crop's roots. Techniques to capture and efficiently utilize the full season's rainfall can transform drought-prone areas into favorable rainfed rice areas. Well designed on-farm reservoirs can alleviate drought and increase system productivity if the soil characteristics, topography, and social context are well integrated with potential cropping patterns. Shallow tube wells are becoming widespread in many parts of Asia. While offering farmers the opportunity to reduce drought and intensify their systems, management of this resource is critical since it also supplies household water in many areas. Deep tubewells, if not properly managed, can deplete "fossil" water reservoirs. For rainfed areas to compete fairly with Irrigated areas—and as rural-urban competition for water resources increases—water must be priced to reflect its true value. Regional water resource monitoring must be developed to assure quality standards and preservation of the resource base. Farmers must be able to sell the additional harvest made possible by increased water-use efficiency.

Potential impacts[a]	Required for Impact	
	Research	Policy tools
1 2 3 **4** **5** 6 **7** **8**	• Effect of tillage and crop establishment methods (e.g., dry direct seeding) on water use; • Genetics and morphology of rice root system development; • Economic and social factors that influence farmer development of on-farm reservoirs; • Pre- and post-rice crops as means to capture residual soil moisture and pre-monsoon rainfall; • Groundwater and shallow tube well management for sustainable supplemental irrigation.	• Water use policies that balance urban and agricultural needs; • Water pricing that reflects true cost and value; • Regional monitoring of water use, availability, and quality; • Rural market infrastructure that is capable of handling increased outputs.

[a] Impacts: **1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less-favored lands;** 2) Reduction of rural poverty and increased farmer incomes; 3 Reduced labor demands for rice cultivation with labor released for other, more productive endeavors; **4) Ricelands freed for other uses as remaining lands become more productive; 5) Water resources freed for nonagricultural uses;** 6 Stimulation and development of rural economies and released pressure for urban migration; **7) Reduced upland and lowland degradation and related downstream effects; and 8) Preservation/enhancement of "environmental health".**

Technology/output: **Expansion of soil volume available to crop roots**

Research context

In large rainfed rice areas, particularly in the lowlands, farmers till the soil with primitive animal-drawn "country" plows. Over the centuries, this has led to very shallow plowpans that rice roots cannot penetrate. A zone of only the upper 10-15 cm allows only a small volume of soil from which rice roots can extract water and nutrients. In some circumstances, the plowpan prevents excessive water loss from the field. However, in many areas where the subsoil IS not very permeable, a rice crop can suffer serious drought or nutrient deficiency while being separated from abundant water and nutrients by a thin very hard layer of soil. Disruption of this layer and/or rice cultivars that can penetrate the layer can significantly improve the capture of water and nutrients and hence system productivity. Mechanization alternatives suitable for small-scale. resource-poor farmers must be developed. Such practices may have significant impact on labor requirements and distribution between men and women.

Potential impacts [a]	Required for Impact: Research	Required for Impact: Policy tools
1 **2** 3 **4** 5 6 **7** **8**	• Soil physical properties of plowpan under rainfed conditions; • Physical and chemical properties of subsoil that permit rice cultivation in absence of plowpan: • Genetics and physiology of the capacity of rice roots to penetrate the plowpan; • Appropriate implements that permit small-scale farmers, especially women, to do deeper plowing; • Effect of alternative tillage practices on female labor; • Impact of deeper rooting zone on post-rice crops.	• Available mechanization alternatives that are suitable for men and women; • Development of local machinery manufacturing capacity and/or placement of favorable import and credit policies; • Support for alternative rural employment opportunities.

[a] Impacts **1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less-favored lands; 2) Reduction of rural poverty and increased farmer incomes:** 3) Reduced labor demands for rice cultivation with labor released for other, more productive endeavors; **4) Ricelands freed for other uses as remaining lands become more productive;** 5) Water resources freed for nonagricultural uses: 6) Stimulation and development of rural economies and released pressure for urban migration; **7) Reduced upland and lowland degradation and related downstream effects; and 8) Preservation/enhancement of "environmental health".**

Technology: **Direct seeded rice-driven transition from single to multiple crops**

Research context

Much of the rain that falls during the early part of the growing season is lost as farmers wait for enough water for soil puddling that will permit rice transplanting. With dry sowing, planting can be done earlier and residual soil moisture after rice can be used to grow a second crop, especially if the rice cultivar is early maturing. Dry-seeded rice may also develop a vigorous and deeper root system that can better extract nutrients and water and allow escape from early season drought. However, puddling is one of the few tools available for farmers to manage weeds, which can be devastating in the tropics. Therefore, if farmers are to intensify their systems and improve resource capture by dry-seeding their rice, they must have the means to manage weeds.

Potential impacts [a]	Required for Impact: Research	Required for Impact: Policy tools
1 **2** **3** 4 5 **6** **7** **8**	• Effects of intensified cropping patterns on long-term physical and chemical status of the soil; • Factors affecting adoption of intensification alternatives (e.g., land tenure patterns and access to markets); • Effect of crop intensification on rural household income and status of women; • Effect of direct seeding on landless labor (especially women); • Weed control options in absence of soil puddling and transplanting; • Yield trade-off between weed-competitive plant architecture and high-yield architecture; • Effect of crop intensificatlon on quality of ground and runoff water.	• Long-term investment in facilities to monitor the natural resource base; • Development of infrastructure for market access in the less favored environments; • Availability of safe, effective, and affordable herbicides.

[a]Impacts: **1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less-favored lands; 2) Reduction of rural poverty and increased farmer incomes; 3) Reduced labor demands for rice cultivation with labor released for other, more productive endeavors;** 4) Ricelands freed for other uses as remaining lands become more productive; 5) Water resources freed for nonagricultural uses; **6) Stimulation and development of rural economies and released pressure for urban migration; 7) Reduced upland and lowland degradation and related downstream effects; and 8) Preservation/enhancement of "environmental health".**

Technology: **Integrated pest and disease management**

Research context

The history of the transformation of irrigated rice in Asia and the Americas tells us that increasing cropping intensity from a relatively low-input system can lead to dramatic shifts in pest and disease complexes. Attempts to manage these through pesticides have led to serious disruptions of the ecological balance in ricefields and to ever-increasing pesticide applications, with accompanying environmental, health, and economic repercussions. Integrated pest management programs in irrigated systems have shown it is possible to reduce drastically pesticide applications with little or no yield losses. As rainfed rice systems intensify, it is important to anticipate the potential changes in pests and to develop integrated pest management approaches before these changes pose a problem. This will require intensive studies on both pests and beneficial insects under rainfed conditions, and careful analysis of what effects new cultivars, diversified production systems, and higher nutrient contents within crop plants may have on these populations. Significant investment will have to be made in order to develop efficient transfer of pest management technology to farmers.

Potential impacts[a]	Required for Impact	
	Research	Policy tools
1 **2** 3 4 5 **6** **7** 8	• Interactions among crop establishment and management practices. plant type. and losses due to diseases. insects, and weeds: • Establishment of decision-making criteria for variable rainfed environments: • Development of durable. pest-tolerant rice cultivars: • The role of biodiverse plant communities in maintaining beneficial insect populations and diversity: • The contribution of genetic diversity in rice to reducing yield losses due to pests: • Opportunities to genetically engineer durable pest resistance using genes from nonrice species.	• Investments in basic research and advanced education on topics ranging from natural plant communities to molecular biology: • Importation and pricing policies for agricultural chemicals that reflect the true cost of pesticide use.

[a] Impacts; 1 Food security and self-sufficiency achieved through at east 30% yield increase on 40 million ha of less-favored lands: **2) Reduction of rural poverty and increased farmer incomes;** 3 Reduced labor demands for rice cultivation with labor released for other, more productive endeavors; 4 Ricelands freed for other uses as remaining lands become more productive; 5) Water resources freed for nonagricultural uses. **6) Stimulation and development of rural economies and released pressure for urban migration; 7) Reduced upland and lowland degradation and related downstream effects;** and 8) Preservation enhancement of environmental health.

Technology: **Regional crop management predictions**

Research context

The variability and diversity of rainfed ricelands make it very difficult to generate broad recommendations for farmers. As we begin to better understand how a rice plant, a rice crop, and a cropping system respond to different climatic conditions. It will be possible to predict performance under specific conditions. Combining this with expected conditions using models based on past trends, we will be able to assess the risk incurred using different practices. Farmers can then be advised on the practices that may be most suitable for them, given their land types, tolerance to risk, and farming objectives. This will require considerable investment in data generation and accumulation as well as extensive innovative computer modeling of the plant, cropping system, and regional weather trends.

Potential impacts[a]	Required for Impact	
	Research	Policy tools
1 **2** 3 4 **5** **6** 7 8	• Reliable weather-sensitive crop growth simulation models that are suited to rainfed systems; • Reliable long-term weather databases and weather simulation models; • Software to link crop growth and system productivity models with regional climate and weather models.	• Development and availability of regional and national databases; • Investment in sophisticated data management hardware, software, and education.

[a] Impacts: **1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less-favored lands; 2) Reduction of rural poverty and increased farmer incomes;** 3) Reduced labor demands for rice cultivation with labor released for other, more productive endeavors; 4) Ricelands freed for other uses as remaining lands become more productive; **5) Water resources freed for nonagricultural uses; 6) Stimulation and development of rural economies and released pressure for urban migration;** 7) Reduced upland and lowland degradatlon and related downstream effects; and 8) Preservation/enhancement of “environmental health”.

Technology: **Export-quality rices**

Research context

As their incomes rise, consumers begin preferring higher quality rice. Production of high-quality rice offers small-scale farmers the opportunity to participate in more profitable trade and can transform subsistence agriculture into export agriculture. The physiology and genetics behind grain characteristics that determine aroma, length, and cooking quality are poorly understood, although they are believed to be complex. Incorporating these desirable traits into adapted cultivars that are suitable for a range of environments and cropping systems will require sophisticated, in-depth research. High-quality rices tend to be less productive than intermediate quality rices, but fetch much higher prices. If farmers move into specialty rice production to increase profits, overall production may suffer. Therefore, policies must be in place to assure supplies of affordable rice for the poor.

Potential impacts [a]	Required for Impact	
	Research	Policy tools
1 **2** 3 4 5 **6** 7 8	• Aspects of cereal chemistry that affect grain quality; • Genetics of grain quality; • Environment x genotype interactions that affect grain quality; • Trade-offs between grain quality and yield; • Effect of widely available, high-quality rice cultivars on rural incomes and land-use.	• Access to international markets and appropriate foreign exchange regulations; • Provisions for meeting basic food needs (e.g., importation of cheaper, lower quality grain).

[a] Impacts: 1) Food security and self-sufficiency achieved through at least 30% yield increase on 40 million ha of less favored lands; **2) Reduction of rural poverty and increased farmer incomes;** 3) Reduced labor demands for rice cultivation with labor released for other, more productive endeavors; 4) Ricelands freed for other uses as remaining lands become more productive; 5) Water resources freed for nonagricultural uses; **6) Stimulation and development of rural economies and released pressure for urban migration;** 7) Reduced upland and lowland degradation and related downstream effects: and 8) Preservation/enhancement of "environmental health".

Notes

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THIRTEEN

Rice research and policy: a first encounter

R.S. Zeigler

The first step of the research-policy dialog, presented in Chapter 12, was a result of intensive discussion among scientists. From the outset, IRRC participants were encouraged to view the research world from a new policy perspective. The considerable scientific outputs were then readily synthesized and linked to key policy tools, albeit from the vantage point of agricultural research scientists. It is from this initial research perspective that the main research-policy dialog began.

The research-policy dialog

The objectives of this exercise were to view the potential research from policymakers' perspectives, to start understanding the multiple constraints and objectives facing policymakers that influence their decisions, and to begin consideration of key leverage points. The expected output of the interaction was a summary of policy-research interactions and, based on these, messages to policymakers and research directors. The participants appreciated that this was but a first step in what would be a long journey in developing a strong relationship between these important leaders in the development process.

Policymakers and research directors from 16 Asian countries plus Australia, Botswana, Brazil and Madagascar (see Appendix) participated in two roundtable discussion groups. Given the limited time available for discussion and synthesis, issues—related to the orientation of the IRRC, i.e., rainfed ricelands—were presented to stimulate discussion. It was not expected that the two groups would resolve the issues. Indeed, some issues are so complex and values-dependent that they may be outside the proper realm of being "resolvable" issues. Discussion questions presented to the groups were:

- What is the proper balance between further investment in the irrigated sector vs. strengthening research and development in the rainfed areas?

- What are the environmental and social impacts of infrastructure developments for rainfed areas?
- Opportunities for new technologies for rainfed rice agriculture: what are the strategic choices?
- How do import-export policies, in light of the General Agreement on Tariffs and Trade (GATT), affect food self-sufficiency· vs. self-reliance?

The groups synthesized the results of their discussions around issues discussed during the IRRC:

- Vulnerability of staple food supply for Asia;
- Meeting the needs of the rural poor;
- GATT and food security vs. food self-sufficiency.

On pages 151-154, each synthesis is introduced by a brief statement placing the topic within a policy framework. Following this, key problems within each issue are identified. Each problem is then restated as an "opportunity." Various problems and opportunities to solve them are presented. Actions, which will be required by both policymakers and researchers to translate the problems into opportunities, are presented as "messages" to each group.

Issue: **Vulnerability of staple food supply for Asia**

Policy context

Growth in Asian populations and economies will drive a 70% Increase in demand for rice by 2030. Virtually all of this must come from Asia itself. However, there are indications that present sources may not be able to meet this demand. The best lands are permanently moving out of rice production because of urbanization, and water is being drawn to urban and industrial uses and other crops, as investment in irrigation slows and agriculture area stagnates. Labor is leaving agriculture for better paying sectors. Evidence of productivity decline is growing in irrigated systems. and rainfed system productivity remains far lower than it should be, given the resource base. Large urban populations will demand reliable, affordable, and high quality food. Key problems are water scarcity, a narrow and vulnerable genetic base for rice, and yield variability in rainfed areas.

		Messages	
Problem	Opportunity	Policy	Research
Water scarcity	More efficient use of existing irrigation facilities and resources	• Develop efficient management and accountability to utilize maximum capacity • Set up appropriate water pricing to reflect scarcity • Approve policies that favor on-farm water storage and efficiency • Negotiate International agreement on water access	• Devise Irrigation management technologies that conserve water • Develop crop production technologies that reduce the net demand for water • Develop technology for efficient on-farm rain "harvesting" and intermittent irrigation
Narrow and vulnerable genetic base for rice	Generation and distribution of genetically diverse rice varieties	• Modify seed certificatlon procedures to allow more flexibility in cultivar traits • Develop an institutional framework for multiple cultivar distribution	• Analyze and utilize biodiversity in cultivated and wild species • Develop tools for managing diverse rice crops
Yield variability in rainfed environments	Development of locally adapted cultivars	• Provide Incentives for the private sector to breed cultivars for the unfavorable rainfed ecosystems	• Develop innovative breeding approaches for unfavorable environments

Issue: **Meeting the needs of rural poor**

Policy context

Asia's rural people, especially those living in rainfed environments, are among the poorest in the world. Gender inequities are often enormous in these rural communities. Population growth and lack of opportunities are driving many, especially young landless men, to migrate to urban areas. Labor is becoming scarce and costly in rural areas, and in urban areas the rate of infrastructure development is often unable to keep up with the rapid influx of people from rural areas. Low-input intensification of rainfed lowlands is leading to lowland degradation. Population pressure and poverty are causing reversal of recent migration trends from uplands to lowlands, which is leading to deforestation over large areas. Deforestation is followed by increased flooding and siltation of dams and irrigation canals in lowlands. Key problems are low incomes, poor human nutrition, isolated farmers, and degradation of the resource base.

		Messages	
Problem	Opportunity	Policy	Research
Low incomes	Diversification of rural agricultural and small industrial economies	• Promote rural electrification and construct farm-to-market roads • Provide affordable and available credit to manage risk	• Conduct systems-based productivity research • Develop small, locally manufactured agricultural machinery
Poor human nutrition	Improve the food base	• Enhance availability of storage and transport facilities for grain and perishable foods • Create value-added food processing industries in rural areas	• Develop alternative high-nutrition crops for growing during the off-rice seasons • Improve the micronutrient content of staple grains
Isolated farmers	Provide farmers with modern techniques and tools	• Revitalize extension services by orienting them to the needs of rainfed ecosystems • Install telecommunications systems in remote regions	• Conduct strategic and applied on-farm research involving NGOs, etc. • Develop practices suitable for low-input systems

Problem	Opportunity	Messages	
		Policy	Research
Degrading the resource base	Promote "conservation" farming	• Install "soil pricing" systems that take into account off-site and future effects of soil degradation • Promote career opportunities for the "best and brightest" • Give high-profile to resource base research	• Develop long-term research perspective on rice-based systems • Utilize biotechnology appiication to enhance positive plant-environment interactions

Issue: **GATT and food security vs. food self-sufficiency**

Policy context

Hundreds of millions of poor rice farmers live in rainfed lowland areas. Due to weather and landform constraints, they can grow no other crop during the wet season and, because of their poverty, they have very limited purchasing power. What is to happen to these people as the General Agreement on Tariffs and Trade (GATT) comes into effect and economies open up? The "thin" international rice market is prone to wide price fluctuations. High dependence on imported rice can leave a small country vulnerable in the event of crop failures in exporting and/or large importing countries. Countries that formerly protected their rice producers for cultural and/or strategic reasons will be forced to open their markets. What will be the impact on local capacity and food availability of cheaper foreign rices? How should long-term strategic issues balance with short-term economic considerations? What actions should a government take to ensure that its rice industry remains competitive? Key problems are that self-sufficiency and food security continue to be strategic issues for many governments and that "public good" technology is moving into the private sector.

		Messages	
Problem	Opportunity	Policy	Research
Continued strategic priorities of self-sufficiency and food security	Increase rice imports as a price stabilizing force, but only on the margin	• Set import targets and plan production figures accordingly • Argue for pricing adjustments that factor in standard of living differences among producer farmers • Remove low productivity and very harsh marginal environments from rice production • Adopt policies to encourage diversification of rice production areas	• Develop efficient rice production technologies that compete with cheapest imports • Develop high grain quality rices that can compete in high-profit international markets
"Public good" technology moving into private hands	Investment of private sector resources into staple food production research	• Clearly define intellectual property rights, gene patenting, and breeders' rights and make sure they meet international standards	• Develop public sector capacity for "frontier" research on staple food crops

The next step

The enthusiasm that met this first attempt at a dialog among researchers, research directors, policymakers, and planners suggests that it is opportune to continue such contact. However, as there is now recognition of the benefits of interaction between policymakers, and researchers, the manner in which it occurs should be carefully considered. There are an enormous number of issues that demand both policy and research inputs. For most issues, only a select group of scientists and policymakers would have the combined expertise to carry on a meaningful dialog. Large meetings, while useful for exchanging information in a conference setting, are not the best fora tor meaningful and in-depth discussions on complex and often politically-sensitive issues.

Water: topic of the next dialog?

To sustain interest in such dialog, the next policy-research interaction should cover a topic of very high priority to both policymakers and researchers. We propose that a suitable issue is water. There are profoundly complex and important scientific and policy issues surrounding management and utilization of water resources, assuring availability, setting price, and allocation across sectors and regions. Indeed, if Asia cannot successfully manage its fresh water resources, the long-term prospects for the region become frighteningly bleak. As a starting point, the issue is addressed at length in *Water: A Looming Crisis,* IRRI's 1994-95 corporate report.

Notes

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