Rice Today

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International Rice Research Institute

September 2002, Vol. 1 No. 2

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ISSN 1655-5422

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Rice Today is published by the International Rice Research Institute (IRRI), the world's leading international rice research and training center. Based in the Philippines and with offices in 11 other countries, IRRI is an autonomous, nonprofit institution focused on improving the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes, while preserving natural resources. IRRI is one of 16 Future Harvest centers funded by the Consultative Group on International Agricultural Research (CGIAR), an association of public and private donor agencies.

For more information, visit the websites of the CGIAR (www.cgiar.org) and Future Harvest (www.futureharvest.org), a nonprofit organization that builds awareness and supports food and environmental research.

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Lao prime minister visits IRRI

IRRI and the Lao People's Democratic Republic reaffirmed their collaboration in rice research, production and training during the April visit of Prime Minister Boun-nhang Vorachith to the institute.

In addition to receiving briefings on IRRI's research agenda and partnerships, Prime Minister Vorachith stopped at the Experiment Station to see the institute's Long-Term Continuous Cropping Experiment (see Grain of Truth, page 30). The prime minister also visited the International Rice Genebank.

IRRI and Laos collaborated on the Lao PDR-IRRI Research and Training Project, funded by the Swiss Agency for Development and Cooperation, from 1990 to 1999. Siene Saphangthong, the Lao minister for Agriculture and Forestry, served as a member of the IRRI Board of Trustees from 1996 to 2001. IRRI maintains a liaison office in Laos.

Edwin Javier (*right*), acting head of the Genetic Resources Center, shows part of the Genebank germplasm collection to Prime Minister Vorachith (*left*) and Heherson Alvarez, secretary of the Philippine Department of Environment and Natural Resources.

New CURE for tackling unfavorable environments

IRRI's Research Program 3 (Improving Productivity and Livelihood for Fragile Environments) recently shifted into high gear with the formation of the Consortium for Unfavorable Rice Environments (CURE). The new consortium merges the former Rainfed Lowland Rice Research Consortium and the Upland Rice Research Consortium to further develop IRRI's and its national partners' ability to do strategic research and to achieve a greater impact in farmers' fields.

The CURE Steering Committee held its first meeting in June in New Delhi, where B.N. Singh, director of the Central Rice Research Institute (CRRI) in Cuttack, Orissa, was elected chairperson. Other committee members are S.B. Siddique, director of the Bangladesh Rice Research Institute; Andi Hasanuddin, director of the Central Research Institute for Food Crops in Indonesia; Soulivanthong Kingkeo, deputy director general of the National Agriculture and Forestry Research Institute in Laos; Leocadio Sebastian, executive director of the Philippine Rice Research Institute; Sutep Limthongkul, deputy director general of the Department of Agriculture in Thailand; and Pham Van Chuong, deputy director general of the Vietnam Agricultural Science Institute.

CURE's activities are implemented through six working groups, based on the major rainfed subecosystems. Elected to lead four of the working groups were IRRI scientists Gary Atlin (drought-prone subecosystems), V.P. Singh (submergence- and flood-prone subecosystems), Sushil Pandey (shifting cultivation systems in hilly Southeast Asia) and Casiana Vera Cruz (permanent cultivation systems in Southeast Asia with long rainy seasons). Steering Committee Chair B.N. Singh will lead the salinity group, and P.K. Sinha, head of the Central Rainfed Upland Rice Research Station in Hazaribagh, India, will head the working group on permanent cultivation systems in South Asia. Group leaders report to Tom Mew, consortium coordinator and Program 3 leader.

The working groups include farmer organizations, NGOs, extension agents, rice scientists and other stakeholders to ensure that the technologies developed become available to farmers as early as possible. Integration across scientific disciplines is achieved by focusing research and development activities at eight key sites that represent the major features of the unfavorable rice environments.

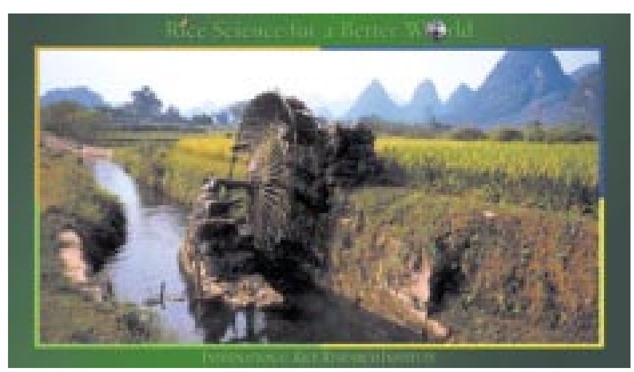
Thailand bullish on expanding research relations with IRRI

Expansion of IRRI-Thailand collaboration in rice research and production promises to result from the June visit to the institute of a high-powered Thai trade delegation led by Prachuab Chaiyasan, trade representative and former foreign minister of the kingdom. Acting on specific instructions from Prime Minister Thaksin Shinawatra, Mr. Chaiyasan and his delegation took special interest in IRRI's current research agenda, the rice genome, the new plant type and progress in biotechnology.

Thailand is a major IRRI partner in rice research, collaborating on several ongoing projects, such as the Consortium for Unfavorable Rice Environments, the Asian Rice Biotechnology Network, the International Network for the Genetic Evaluation of Rice, and efforts to develop aerobic rice germplasm for water-scarce tropical environments and to improve livelihoods and profitability for rice farmers in northeast Thailand.

The delegation included high officials of the Thailand Trade Representative Office, the National Center for Genetic Engineering and Biotechnology, the Ministry of Science, Technology and Environment, the Patum Rice Mill Granary Public Company Limited, and rice miller, exporter and farmer associations.

IRRI's Communication and Publications Services won two silver awards in the graphic design category of the 2002 international competition sponsored by Agricultural Communicators in Education. One award went to the set of four landscape posters (the poster shown here is Guilin, China, by Rob Kendrick), and the other was for the jewel box and CD design for the RiceIPM CD.



Rice scientists win major environmental prize

An innovative campaign that promises to help protect a million rice farmers in the Red River Delta of Vietnam from the harmful effects of dangerous insecticides won one of the world's major environmental prizes. The collaborative effort, led by K.L. Heong *(right)*, a senior entomologist at IRRI, M.M. Escalada (*second from left*), a professor of development communication at the Philippines' Leyte State University, and Nguyen Huu Huan (*left*), the vice director general of Vietnam's Plant Protection Department, received the $25,000 Saint Andrews' Environmental Prize in May at a ceremony in Scotland. (Also shown is Vo Mai, former vice director general of the Plant Protection Department.)

First launched in 1994 in the Mekong Delta, the research and subsequent campaign marked a milestone in rice production for two reasons. First, it clearly identified the damage caused by the overuse of insecticides, which kills off friendly insects and so encourages the pests they would otherwise help control. Second, it developed a new way of communicating important information to farmers, using short radio dramas supported by leaflets and posters.

"We got a group of actors to play out a series of brief comedies, using rustic situations and solid scientific facts to make the audience laugh," Dr. Heong explained.

After testing their campaign in the Mekong Delta, where almost 2 million rice growers sharply curtailed their pesticide use, the research partners launched, on World Environment Day in June 2001, a similar, ongoing campaign in northern Thailand's Sing Buri Province. Now they will use the Saint Andrews' prize money to extend the campaign to another million rice farmers in the Red River Delta.

In announcing the winners, Sir Crispin Tickell, the chairman of the St. Andrews' Prize Board of Trustees, said: "In the end we decided to give the prize to a proposal of obvious and lasting benefit to millions of people, which could and should be a model for others."

Briefly

Korea-IRRI workplan set

Under a new workplan for 2002-03 agreed in April between IRRI and the Rural Development Administration (RDA), ten ongoing projects and four new ones will focus on improving varieties, hybrid rice, biotechnology, and developing data-management systems for rice breeding. Germplasm exchange and special projects on developing super-yielding *japonica* rice cultivars suitable for direct seeding in the temperate region will continue. The program of scientist exchange and training to support Korea-IRRI collaboration was also extended. Initiatives will involve molecular breeding of *japonica* rice for biotic and abiotic stress resistance and a joint training workshop on Rice Technology Transfer Systems in Asia to be held on 29 September-12 October in Korea. The workshop aims to identify the components of successful research-extension linkage as exemplified by the Korean system, analyze technology transfer systems throughout Asia, and initiate regional cooperation and networking among countries and institutions for technology delivery.

IRRI reduces staff

In response to steep funding cuts, IRRI embarked in May on a retrenchment program to cut its annual payroll for nationally recruited staff by US$1.5 million. The program, slated for completion in September 2002, is expected to reduce the number of nationally recruited staff from 850 to 650. In addition, internationally recruited staff numbers — including scientists, postdocs and graduate students — will drop from 150 to 135. (See commentary on page 7.)

Hybrids nominated

The Rice Varietal Improvement Group of the Philippines decided in May to nominate two IRRI-developed hybrids for release as new varieties to the National Seed Industry Council. The hybrids IR75207H and IR75217H had undergone four seasons of trials conducted in various parts of the Philippines.

Improved IPM course launched

Almost a decade after IRRI offered its last course on integrated pest management (IPM) in 1993, a new, four-week IPM training course was launched in April. Eighteen IRRI scientists and four other specialists in the United Kingdom, Australia and the Philippines helped develop the courseware, which summarizes various facets of IPM.

Awards pile up

IRRI scientists' posters, papers and research achievements won three awards in April at the 32nd Annual Scientific Conference of the Crop Science Society of the Philippines and another four awards the following month at the 33rd Annual Scientific Conference of the Pest Management Council of the Philippines.

PhilRice calling

Luis Lorenzo, Jr., Philippine presidential adviser for A Million Jobs and chair of the Board of Trustees of the Philippine Rice Research Institute (PhilRice), visited IRRI in March, along with PhilRice Executive Director Leocadio Sebastian and PhilRice Los Baños Station Officer-in-Charge Diego Ramos. The visit further bolstered IRRI-PhilRice collaboration in rice research.

IRRI IN THE NEWS

Supercharging photosynthesis

by *Christopher Surridge*

Feeding the world in the 21st century could require a second Green Revolution and the most audacious feat of genetic engineering yet attempted

First, some sobering facts and figures: over the next 50 years, the world's population is expected to increase by a third, to some 8 billion. Much of this rise will be in Southeast Asia, where half the population is already poorly nourished.

Global production of rice (*Oryza sativa*), the world's most important staple crop, has risen threefold over the past three decades — and if similar progress could be maintained, there should be enough food to meet the rising demand. But here's the rub: yields are fast approaching a theoretical limit set by the crop's efficiency in harvesting sunlight and using its energy to make carbohydrates.

So to feed the world, rice may have to be reengineered at the biochemical level. "The only way to increase yields and reduce the use of nitrogen fertilizers is to increase photosynthetic efficiency," argues John Sheehy, an ecologist at IRRI who specializes in modeling crop yields. He calculates that a boost of 20% should do the trick.

Easily said, rather more difficult to do.

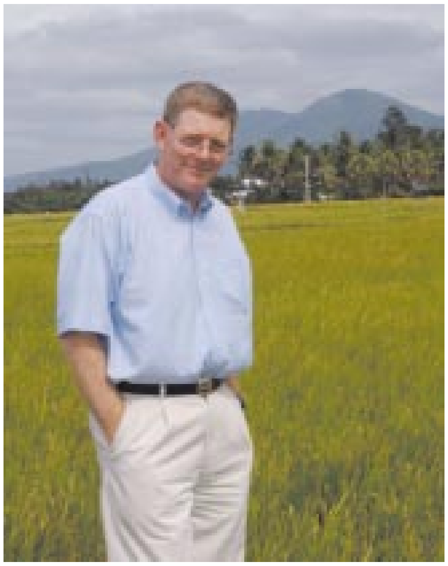
The first Green Revolution, which began in the late 1960s, depended on dwarf varieties of rice, wheat and maize that, put simply, made more grain for less stem. It has since been shown that this relied on breeding mutants that do not produce, or fail to respond to, the plant hormone gibberellic acid.

Now we can add the techniques of genetic engineering to the old methods of mutation and traditional plant breeding. The modified crops created so far generally involve the addition of a single gene — for a natural insecticide, say, or tolerance of a herbicide. For geneticists, this is like improving a car's performance by adding an aerodynamic spoiler or changing the tires. But boosting a plant's photosynthetic efficiency will involve manipulating a whole suite of genes. By the same analogy, it's like supercharging a car's engine by fitting a new fuel injection system.

Thankfully, evolution provides plant scientists with precedents. On at least 30 separate occasions, different plant lineages have evolved to use the sun's energy more efficiently, making sugars in a two-stage process known as C_4 photosynthesis. Exactly when this trick first evolved is unknown, but from about 10 million years ago, falling concentrations of carbon dioxide in the atmosphere gave plants using C_4 photosynthesis an important selective advantage. The ancestors of maize were among these plants. But rice, wheat and most other cereals all use conventional C_3 photosynthesis.

Given that it would involve major changes in both biochemistry and anatomy, turning rice into a typical C_4 plant is no trivial matter. But that hasn't stopped some plant scientists from tinkering with the genes that control photosynthesis reactions in an effort to imbue rice with some C_4 characteristics.

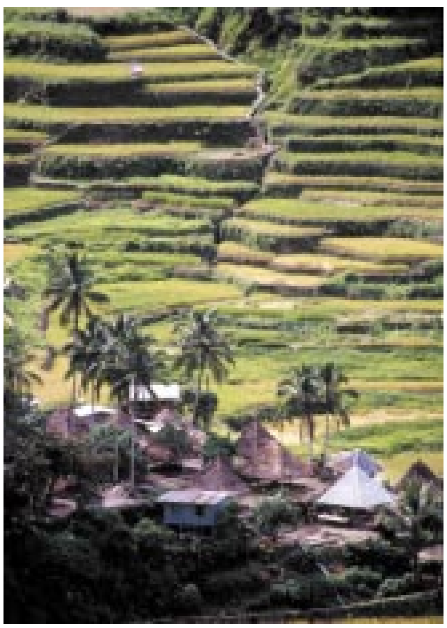
And, given such obstacles, turning rice into a C_4 plant is an endeavor that could take



John Sheehy (*above*) ponders a feat of genetic engineering audacious as the rice terraces of Banaue in the Philippines (*opposite*).

a decade or two. Aside from the scientific challenges, funding could become an obstacle. Japan is the most significant benefactor for rice research, and its largesse will be needed to support efforts to re-engineer the crop's photosynthetic efficiency. But given the present state of the country's economy, Japan has slashed its support for IRRI, which is the natural home for the project.

Many of the nongovernmental bodies committed to fighting world hunger, meanwhile, remain vehemently opposed to



plant genetic engineering — which they see as a method of enriching multinational companies, rather than a means of achieving food security for developing countries.

But enthusiasts argue that super-charging photosynthesis in rice to achieve a second Green Revolution might be just the project to change hearts and minds. "This is the next frontier," Sheehy asserts.

Abridged from The rice squad, *by Christopher Surridge.* Nature, *Vol 416, 11 April 2002. Reprinted with permission.*

Good news – and bad

IRRI and rice have been in the news this year. January saw the publication of an in-depth, four-part series on Golden Rice in the New Jersey-based *Star-Ledger*, one of the top U.S. daily newspapers in terms of circulation and syndication. IRRI is developing tropical varieties of this transgenic rice rich in provitamin A, which series author Kitta Macpherson describes as "the world's first example of food genetically engineered to convey a benefit directly to the consumer." To view the articles, log on to www.nj.com/specialprojects/index.ssf?/specialprojects/rice/main.html

In April, rice featured prominently in two leading peer-reviewed scientific journals. *Science* published research results, reports and commentary on the sequencing of the rice genome (see page 8).

Nature highlighted the quandary that faces publicly funded rice research: as recent and ongoing scientific advances offer an unprecedented wealth of promising new technologies for improving food security and livelihoods for poor rice farmers, steep funding cuts severely hamper the ability of scientists to capitalize on this potential.

Read on...

Poor nations' crop research hurt by Japanese cutbacks

David Cyranoski, Tokyo

With recent breakthroughs such as the draft rice genome sequence, agricultural researchers should have plenty to look forward to. But the research centers that are best placed to tap that promise are facing a funding crisis.

Japan, a major supporter of such research, cut funding for the Consultative Group on International Agricultural Research (CGIAR) by almost half, from last year's ¥3.6 billion (US$29 million). The CGIAR's 16 institutes form the main global network of research centers addressing the agricultural needs of poor countries.

The impact was felt immediately at IRRI. "Japan had been our largest and most faithful donor," laments Ron Cantrell, the institute's director general.

The impending cut led IRRI, following a board meeting in April, to reduce staff levels by over 20% to 785. In addition, some projects will be scaled back. The cuts will not affect the maintenance of the world's largest collection of rice germplasm, which is kept at the institute, Cantrell says.

The situation is especially frustrating because so many data are now available for agricultural research, says Cantrell. "The world is bursting with new technologies," he says. "We are really on the cusp of something exciting."

Adapted from Poor nations' crop research hurt by Japanese cutbacks*, by David Cyranoski,* Nature*, Vol. 416, 25 April 2002. Reprinted with permission.*

Green Revolution gene is sequenced

In a "brief communication" in *Nature* (Vol. 416, 18 April 2002), scientists from IRRI (Swapan Datta and Gurdev Khush) and Nagoya University and Wako Research Center in Japan reported that they have sequenced the gene *(sd1)* that kicked off the Green Revolution and probably saved tens of millions of Asians from starvation. IR8, a semidwarf variety devised by IRRI, dramatically doubled grain yield at a time when populations were growing alarmingly.

"We have introduced this *sd1* gene into Basmati 370 and Azucena rice varieties, resulting in shortened plant height," says Dr. Datta. "This demonstrates the future impact of this study in aiding breeders to improve traditional varieties that will lodge less, ensuring higher yields."

Swapan Datta.

The cereal of the world's poor takes center stage

Ronald P. Cantrell and Timothy G. Reeves

The milestone publication in the 5 April 2002 issue of *Science* (Vol. 296) of not one, but two, draft genome sequences of rice (*Oryza sativa*) brings the cereal crop of the world's poor to center stage. Just 16 months earlier, the science community caught its first glimpse of the completed genome sequence of *Arabidopsis thaliana*, an economically insignificant but "research-friendly" weed related to the cabbage and mustard family. Only 64 days later, Celera and the International Human Genome Sequencing Consortium published draft sequences of the human genome itself.

We believe that the scientific community will conclude that sequencing of the genomes of two rice subspecies will be the first sequencing project to yield tangible results for humankind from the standpoints of food security and combating malnutrition. The draft sequence of the *indica* rice subspecies by the Beijing Genomics Institute (BGI) and of the *japonica* subspecies by Syngenta will have a global impact on human health. These drafts will be combined with a complete rice genome sequence being compiled by the public International Rice Genome Sequencing Project (IRGSP) coordinated by the Japan Rice Genome Program. The IRGSP sequence is expected to be published later this year. The BGI and Syngenta draft sequences do not diminish the value of IRGSP's public sequencing effort. Indeed, all three versions contribute to the completion of a truly accurate rice genome road map that will be invaluable to plant biologists and agricultural scientists. The highly accurate IRGSP sequence will serve as the gold standard for all future investigations of genetic variation in crops.

If a single plant species were to be voted the most popular by scientists and laymen alike, it would be *Oryza sativa*. Rice, the world's most important cereal crop for human consumption, is the food staple of more than 3 billion people, many of them desperately poor. In addition, rice — like *Arabidopsis* — is a model experimental plant; it has a much smaller genome than those of other cereals and a high degree of collinearity with the genomes of wheat, barley and maize. The blending of the complete *Arabidopsis* and rice genome sequences will forever change the way we approach plant biology research. The new genetic knowledge and tools derived from these sequences will help scientists to address intractable problems that limit crop productivity in the developing world. Syngenta reports that 90% of the rice genes on a microchip can be used to probe gene expression in maize — just one example of the value of rice sequence information for elucidating the biology of other important crops.

IRRI, the International Maize and Wheat Improvement Center (CIMMYT) and the other 14 Future Harvest centers of the Consultative Group on International Agricultural Research (CGIAR) welcome the public and private efforts to sequence the rice genome. The CGIAR relies on the sharing of genetic information and seed stocks to develop technology and products for the developing world.

The sequencing of the rice genome will benefit many other plant genomics initiatives that rely upon publicly available genome sequence data. During a May 2001 meeting at CIMMYT, experts developed strategies to promote the application of genomics research to the improvement of cereal crops. This initiative is now part of the U.S. Agency for International Development's effort to assist the agricultural sciences in developing countries. In addition, the U.S. Congress is considering proposals to support a cereal genomics program that will champion collaboration among U.S. universities and the CGIAR centers. Also, the CGIAR is actively implementing a new collaborative research model called "challenge programs," which target CGIAR goals of regional or global significance that require partnerships among a wide range of institutions. Genomics has the potential to address many different aspects of crop research, including genetic diversity and productivity improvement. In addition, genomics research will help us to understand how plants tolerate abiotic stresses, such as drought or salinity, and biotic stresses, such as disease or predation by insects. CIMMYT, IRRI and other CGIAR centers are actively engaged in these efforts.

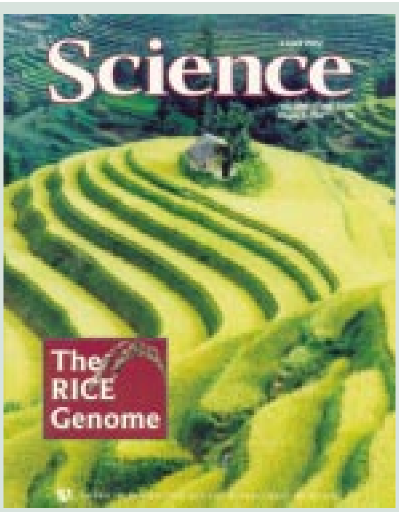
Recognizing the immense value of genomics research to crop improvement, IRRI, in collaboration with its partners in national agricultural systems that conduct and disseminate research, is preparing to take advantage of this treasure trove. IRRI advocates broad collaborations in rice research that embrace innovations by both the public and private sectors, with emphasis on the need to provide the best science to serve the poor. IRRI is pursuing a public research platform through an International Rice Functional Genomics Working Group. The public availability of the rice sequences published in *Science* will boost this commitment.

> Rice will be the first genome sequencing project to yield tangible results for humankind from the standpoints of food security and combating malnutrition

The continuing challenge is to broaden the developing world's access to information and technology. We must provide not only finished products but also the technologies that will enable a new generation of researchers in developing countries to solve their food production problems.

Providing affordable and nutritious food must be an integral part of any development program that aims to improve the lives of the poor. In today's volatile world, we believe that collaborative research in the public and private sectors across developed and developing countries will contribute to reducing international tensions. We congratulate BGI and Syngenta on their milestone contribution to science and to humankind.

Adapted from a perspective in the 5 April 2002 issue of Science *(Vol. 296). Ronald P. Cantrell is the director general of IRRI. Timothy G. Reeves is the director general of the International Maize and Wheat Improvement Center. Reprinted with permission from* Science.



Back to the source: the rice genome in *Science*

When *Science* published draft sequences of the genome, or genetic makeup, of the *indica* and *japonica* su bspecies of rice in its groundbreaking 5 April 2002 issue, the prestigious journal included a cornucopia of associated news stories and commentaries. The feast begins with an editorial by Donald Kennedy, the editor-in-chief of *Science*, defending the controversial decision to publish the Syngenta paper without requiring the corporation to follow the usual practice of depositing its research data in GenBank.

One news feature details the history and fortunes of the International Rice Genome Sequencing Project (IRGSP) in Japan, which is slated to publish a highly detailed and accurate sequence by the end of this year. Another tracks the meteoric rise of the Beijing Genomics Institute, which produced the *indica* draft sequence. Two letters call for continued support for completing the IRGSP sequence and closer collaboration "toward the common goal of a finished and accurate genome sequence." A pull-out section highlighting rice genomics makes an attractive poster.

There are no fewer than four perspective essays related to the rice genome. One of these analyzes the potential, and the responsibility, of science to abolish world poverty and hunger. Another focuses on the opportunities that genomic sequencing brings to comparative plant biology. Reprinted here are abridged versions of the remaining two perspectives, which reflect the views of two key figures at IRRI and their coauthors, as they consider this historic milestone in the ongoing history of rice science for a better world.

More precious than jade and pearls...

Pamela Ronald and Hei Leung

"The most precious things are not jade and pearls but the five grains." The five grains referred to in this Chinese saying are most likely to be rice, wheat, millet, sorghum and maize. These cereal grains account for up to 60% of the calories consumed by people in the developing world. We could also apply this saying to the valuable genetic information that cereals contain — especially rice. With a genome significantly smaller than those of other cereals, rice is an excellent model for genetic and molecular studies. The publication of draft genome sequences of two major subspecies of rice (*indica* and *japonica*) in the 5 April 2002 issue of *Science* (Vol. 296) provides a rich resource for understanding the biological processes of plants and promises to positively affect cereal crop production.

If the world's population continues to grow as predicted for the next 20 years, global cereal yield must increase 80% over the 1990 average to feed these additional people. Compounding the problem is that areas of productive farmland continue to be lost through urbanization and degradation of existing agricultural soils. Although achieving food security will require a multitude of social and economic solutions, the new knowledge derived from genomics research will make an important contribution. The challenge ahead for the plant research community is to design efficient ways to tap into the wealth of rice genome sequence information to address production constraints in an environmentally sustainable manner.

Taxonomically, all cereals belong to one of the two major groups of flowering plants, the monocotyledonous plants (monocots). Completed in 2000, the genome sequence of the weed *Arabidopsis thaliana* provided our first complete view of the genome of a dicotyledonous plant. With the availability of the rice genome sequence, we can now directly compare the genome of a monocot to that of a dicot and to genomes of other sequenced organisms. A significant observation is that over 80% of *Arabidopsis* genes have close counterparts (homologs) in rice, whereas only 50% of rice genes have homologs in *Arabidopsis*, suggesting that all rice genes are essentially a superset of *Arabidopsis* genes. Furthermore, at a significant level of similarity, 85% of proteins examined in cereals have a related protein in rice. This observation poses some interesting questions regarding what the additional rice genes do. Assuming functional conservation, the extensive DNA sequence similarity between rice and other cereals will provide a shortcut to the isolation of genes of agronomic importance in cereals as well as in other crop species. Thus, genomewide analyses affirm that rice is indeed a model species for cereal research with practical applications in both monocots and dicots.

Comparative genomic analysis enables biologists to assign a tentative function to a gene according to what that gene does in another species. Genes controlling disease resistance, tolerance for abiotic stresses, or synthesis of essential vitamins can also be predicted by comparative genome analysis. This information facilitates the

formulation of clearly defined hypotheses regarding which genes govern specific biochemical and metabolic pathways. Experiments can then be designed to determine whether the gene of interest has the predicted contribution to that pathway.

In practice, plant improvement will continue to rely largely upon the accumulation of genes with moderate effects. Once the function of a gene is verified, new plant varieties can be developed by introducing the gene through traditional breeding in combination with marker-assisted selection or direct engineering of the gene into rice or other grains.

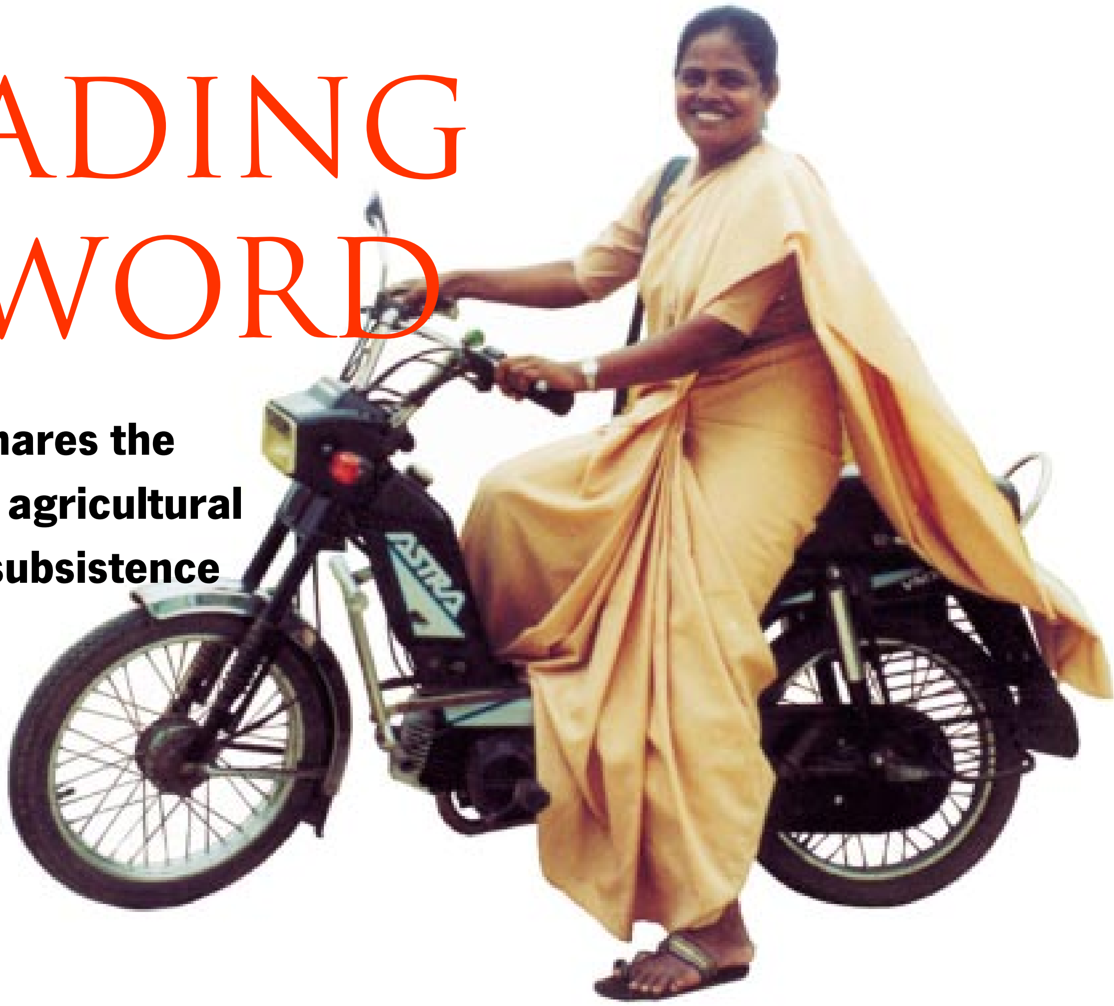
Finally, knowing the sequence of specific genes will allow us to tap into the natural genetic variation of crop species. In rice, there are over 100,000 accessions of traditional rice varieties and wild species (together referred to as germplasm) collected from a broad range of geo-climates and held in trust in the IRRI Genebank. These rice seeds serve as a pool of "natural variants" with the advantage that some of these variants (alleles) have already been "tested" through years of natural or artificial selection under different environmental conditions. To date, this wealth of information has remained largely untapped, owing to the difficulty of identifying agronomically important genes. Now, if a gene has been proven to contribute to a trait of agronomic importance, alleles of this gene can be examined from multiple varieties for their relative usefulness.

For this purpose, the highly accurate genome sequence (<1/10,000 error) being generated by the International Rice Genome Sequencing Project (IRGSP) will be invaluable. The convergence of the different versions of the genome sequence by the end of 2002 will yield great insights into the relation between sequence diversity and functional diversity in a wide variety of germplasm, the foundation on which agricultural productivity depends.

The availability of the rice genome sequence will now permit identification of the function of every rice gene. Once such a catalog is complete, a greater challenge will be to analyze the behavior of the encoded proteins in particular contexts and to determine their interactions with relevant cellular machinery to "generate function at a higher level." For example, why do genes encoding C_4 enzymes in rice (a C_3 plant, see *Supercharging photosynthesis* on page 6) behave differently from their counterparts in photosynthetically more efficient plants such as maize and sorghum? Is it due to differences in the control of gene expression, compartmentalization of the proteins, or interactions with other cellular components? Answers to these and other questions are now within our reach. Applying the information to food production will require creative, integrated approaches using diverse germplasm, traditional breeding, modern technologies and future knowledge from comparative genomics.

Abridged from a perspective in the 5 April 2002 issue of Science *(Vol. 296). Pamela Ronald is in the Department of Plant Pathology, University of California-Davis. Hei Leung is a plant pathologist at IRRI. Reprinted with permission from* Science*. Copyright 2002 American Association for the Advancement of Science.*

SPREADING THE WORD



A religious sister shares the benefits of modern agricultural science with poor subsistence farmers in eastern India

Sylvia O. Inciong

India is a world away from Indiana, and none would mistake Sister Sajita Isaac for Johnny Appleseed. But the peripatetic Catholic nun calls to mind the fabled nurseryman of the American frontier. Like John Chapman — to use the real name of the evangelist who roamed Indiana and Ohio for half a century raising apple seedlings to sustain homesteaders during their first difficult years — Sister Sajita brings missionary zeal to the earthly task of helping farmers improve their diets and livelihoods. And, like Chapman, she covers a lot of ground, riding her motorbike five days a week to villages up to 50 km away, and shifting her agricultural ministrations from village to village as improved crop varieties and farming practices take root.

Unlike Johnny Appleseed, Sister Sajita is not a self-taught, solitary wanderer, but a participant in an international network of partnerships forged to disseminate the benefits of modern agricultural science among poor subsistence farmers. Nationally, the Indian Council of Agricultural Research funds a network of hundreds of *krishi vigyan kendra* (KVK), or "farm science centers," to test and transfer agricultural technologies and to boost self-employment opportunities in farm communities. Sister Sajita serves through Holy Cross KVK of Hazaribagh, Jharkhand, 970 km southeast of New Delhi, which over the past 15 years has extended agricultural outreach to more than 500 villages.

Through Holy Cross KVK, located at the foot of the scenic Kanary Hills 5 km northeast of Hazaribagh, farmers receive seeds of improved rice varieties, training in seed production and seed health, guidance in how to diversify into other crops and improve animal husbandry, and counseling in nutrition, hygiene and organizing self-help groups focused on savings mobilization and gender issues.

"As early as 1973, our Holy Cross congregation was doing well in medical services, education and women's development, but not in agriculture," recalls Sister Sajita, who was born in the southern Indian state of Kerala and joined Holy Cross at the age of 17. "Our lack of expertise in agriculture was glaring, as 70% of the people in this area are farmers." At about 600 meters above sea level, the farmlands of the hardscrabble Hazaribagh Plateau depend on the vagaries of rainfall, though in some areas farmers draw limited irrigation from wells and water-harvesting ponds. Poverty remains pervasive.

OUTGOING PERSONALITY

Selected to head the congregation's new agricultural outreach program on the strength of her outgoing, approachable personality, Sister Sajita prepared for the job by earning a master of science degree in horticulture. She also traveled to the Philippines for further studies at IRRI and the International Institute of Rural Reconstruction.

In 1980, she returned to Hazaribagh to put her new expertise to work. Although she typically arrives unheralded in targeted villages, from the moment she enters farmers' homes, they begin telling her about their problems and aspirations. "The farmers trust Holy Cross KVK," she observes.

Virendra Pal Singh, an IRRI agronomist who has worked in eastern India for a dozen years, appreciates the value of that trust and the access to farmers that it provides. IRRI began collaborating with Holy Cross KVK in 1989.

"We recognize that problems can be resolved more easily and quickly through local collaboration," says Dr. Singh, explaining that well-chosen partners can speed the learning process and stretch scarce resources for research and extension. "Partnership makes it possible to disseminate innovations to farmers more rapidly."

Following a round of farmer training jointly conducted by IRRI and Holy Cross KVK, the partners launched trials of rice varieties developed by IRRI and India's Central Rainfed Upland Rice Research Station, first on Holy Cross KVK's 10-hectare demonstration farm, then in farmers' fields. One such variety, RR167-982, has since been released under the name Vandana. Another measure of success, Sister Sajita notes, is farmers' eagerness to receive and try out the seeds of improved varieties bred for pest resistance, drought tolerance and early maturity.

As few farmers can produce good-quality seed without special training, Holy Cross KVK allocates a portion of its demonstration farm to multiplying the seeds of modern varieties for subsidized sale to farmers. Farmers also receive training in seed selection and managing seedling beds, typically mastering the techniques in four cropping seasons. IRRI and Holy Cross KVK also help farmers develop rice-based farming systems with broader crop diversity to maximize sustainable productivity and profitability.

"Years ago, all they grew was rice," recalls Dr. Singh. "Now many of the farm families here grow vegetables for sale, which improves their income."

MUSHROOMS GROWN ON RICE STRAW

A recently introduced cash crop is mushrooms grown from October to March on straw saved from the previous rice harvest. "We're piloting this project in three villages, " Sister Sajita says, adding that initial earnings from mushrooms can be 15,000–20,000 rupees (US$300–400) per harvest.

"We usually work with farmers for at least two years," Sister Sajita explains. "And when we see them taking on the new technology, we move on to other places."

Ongoing social work, in particular improving the lives and capabilities of women farmers and farm laborers (who perform 60% of the work of paddy cultivation), includes gender analysis and group exploration of options for solving problems. As chronic indebtedness is pervasive, Sister Sajita helps rural women organize credit cooperatives to tide members over hard times without resorting to high-interest loans.

Within four or five years, she reports, many rural women manage to accumulate bank accounts worth 30,000–40,000 rupees (US$600–800) — nurseries of prosperity on this Indian frontier.

Seed health and gender analysis are among the teachings of Sister Sajita.

Laser lite

A SLIMMED-DOWN TECHNOLOGY HELPS CRAMPED ASIAN FIELDS PRODUCE RICE AT THEIR LEVEL BEST

This computer-generated graphic illustrates how a laser instrument atop a tripod beams an invisible, perfectly flat disc of laser light that strikes a receiving unit mounted on the box scraper. The receiver unit controls a hydraulic system that raises or lowers the blade as the box scraper is pulled around by a tractor, scraping up or dumping soil depending on whether the field surface is high or low. The result is a field level to within 1 cm.

In northeast China, harvesting machinery bogs down in poorly drained fields as farmers race to bring in the rice crop before it freezes. In the arid Xinjiang region of northwest China, cotton fields guzzle precious water resources and gag on the soluble salts evaporation leaves behind. John Coulter has long known that laser land leveling could solve both problems, but the 20-year veteran of technology transfer to China struggled to make it happen.

"In 1995, I was chief representative in China for a large American farm-machinery manufacturer," he recalls. "When I told the Heilongjiang State Farm Bureau divisional chief of farm machinery that he needed laser leveling, he cut me off in mid-sentence, angrily denouncing lasers as expensive and a waste of time. I later learned that he had imported laser equipment and tried to use it without adapting it to local conditions."

By 1999, Dr. Coulter was a private consultant commissioned by the World Bank to design a laser-leveling procurement-and-transfer package for the expanses of Xinjiang. "The fields out there can be as big as where I come from in Australia," he recalls, "so I knew big, imported equipment would be best" — a scraper at least 3.6 meters wide, pulled by a minimum 250-hp tractor. The price tag topped US$200,000, horrifying the Chinese.

Pioneering work

Today, Dr. Coulter is a self-funded researcher based at China Agricultural University in Beijing, where Wang Maohua, an energetic and influential academician of the Chinese Academy of Engineering, raised the idea of small-scale laser leveling. Dr. Coulter recalled pioneering work

Factory to farm

Laser leveling can get off the ground — in China and elsewhere — only where it is commercially viable. John Coulter envisions it developing in China, as in the West, as a contractor service. He estimates a contractor's capital outlay at about 60,000 yuan (US$7,250): 6,000 yuan for a factory-built box scraper (parts for the prototype cost 4,300 yuan; materials will be cheaper in a factory run, but labor and a profit margin will be included), US$3,250 (26,800 yuan) for the imported laser instrument, and about 30,000 yuan for a Chinese-made, 65-hp tractor (assuming the contractor already has one and values it at half of its 60,000 yuan purchase price).

The window between harvest and replanting ranges from a few days to two months — so assume 20 days of operations per year. Amortization over five years (100 days of cash flow) comes to 600 yuan per day. Adding operating costs, the contractor needs to earn just over 1,000 yuan per day. At four hours per hectare under average conditions, the contractor can level two hectares per day and offer a quote of just over 500 yuan (US$60) per hectare. In Chinese terms, farmers can level and consolidate their fields for less than 40 yuan per *mu*.

China has 45 million hectares under rice (including terraced hillsides), of which 20 million hectares, by Dr. Coulter's estimate, represent potential demand for laser leveling. A target of laser leveling half of that in the next decade would create a market in the next few years for 25,000–30,000 box scrapers.

In Beijing (*from right*), Dr. Coulter, Prof. Wang, Mr. Rickman and Wang Zhiqiang, workshop director.

done in Cambodia by Joe Rickman, head of IRRI's Agricultural Engineering Unit. Last April, he contacted his fellow Australian, who ordered a laser unit to be shipped directly from the United States to Beijing. It arrived in May, and Mr. Rickman flew to Beijing in June.

"It was a pleasure to be able to get Joe up here," says Dr. Coulter, "and put him in touch with Prof. Wang."

Asked where the box scraper would come from, Mr. Rickman replied that they would build it in Beijing using local parts — mainly steel plate, wheels and simple hydraulics. "Get the general specifications," he said, "then be flexible enough to buy whatever is common." Within three days of his arrival, Mr. Rickman and the university team had ferreted out the parts and welded and assembled them. On the fourth day, they demonstrated the 2.2-meter-wide device behind a Chinese tractor.

"There's nothing new about laser leveling," says Mr. Rickman, adding that it has been common for years on large farms in Australia and the Americas. "All we did was downsize it so Asian farmers could use it."

Mr. Rickman and his collaborators in the Cambodia-IRRI-Australia Project also quantified the benefits to small farmers of leveled fields, in which shallow flooding is sufficient to wet the soil for plowing and maintain coverage for weed control. "In the fields we monitored in Cambodia, we cut water use by about 10% and reduced weed pressure by about 40%," Mr. Rickman reports. "Farmers can use direct seeding more effectively, which reduces labor inputs, and their crops mature more evenly, which improves grain quality and yield." Research found that leveling alone boosted yields by 15%. As leveling temporarily disrupts soil-nutrient availability, correcting for this by applying additional fertilizer, especially phosphate, improved yields by a further 17%.

Improved efficiency

Leveling gives farmers the freedom to shape paddies for maximum workability, improving water-use efficiency and reducing the number and size of bunds, for a typical cropping-area gain of 4–7%. In addition, shallow flooding allows farmers to grow short-stemmed rice varieties offering high yield potential.

A farmer can level a field with a harrow and leveling board, but this requires total water coverage and seven or eight days per hectare using a two-wheeled tractor, or 12 days per hectare using draft animals. A four-wheeled tractor pulling a box scraper can perform the same task in a dry field in four hours. Using a laser makes the job easier and the result more precise.

To preserve the leveling, farmers are encouraged to plow from the center of the field out, rather than from the periphery in, a traditional habit that hollows out the center. According to Mr. Rickman, a properly plowed field should not need wholesale re-leveling for at least eight to ten years.

"The technology works, as we've shown in Cambodia, Thailand and India," he says. "But not if it stalls in academia. We push interested national partners to link up with the private sector, then we lend them the laser instrument and help them build the box scraper."

With Prof. Wang promoting the system far and wide, Dr. Coulter is confident that manufacturers won't be far behind. Plans were afoot to invite visitors to the International Rice Congress in Beijing in September (see Events, page 28) to view a demonstration at the China Agricultural University's experimental farm. "It's not on the conference agenda yet," says Dr. Coulter, "but what Prof. Wang says, happens."

Dr. Coulter proposes that the Chinese call the laser box scraper *zhou xiang.* The name means "black box" and sounds like "Joe box" — honoring the IRRI agricultural engineer who took the mystery out of bringing the benefits of superior land leveling to Asian farmers.

SOWING PEACE IN SOUTH ASIA

A cropping system that unites millions of farmers across South Asia promises to play a key role in helping to achieve peace and stability in Afghanistan

Rice and wheat are traditionally planted in rotation in eastern Afghanistan, as they are on much of the Indo-Gangetic Plain, which extends east of Afghanistan through Pakistan, India, Nepal and Bangladesh. Restoring a productive rice-wheat system in Afghanistan is essential to reviving Afghan agriculture, ensuring food security, and setting the war-torn country on the road to economic recovery.

"We must focus our attention on reestablishing food security as quickly as possible," said a senior aid official. "Restoring Afghanistan's agricultural sector has multiple benefits. Historically, 80% of the population depends on farming and grazing. Revitalizing this sector not only will reduce dependency on international food assistance, but give employment to former combatants, help stabilize the security environment, and spur the economy."

The World Bank estimates that cereal production, the mainstay of Afghanistan's food security, has fallen by almost 40% since 1999 and is only half of what it was during the prewar years. In addition to wheat, rice is a major staple for the Afghan people, who consume on average 17 kg per capita per year (equal to 30 kg of unmilled rice). Historically, Afghanistan is largely self-sufficient in rice. However, in the past decade, when the country's total rice requirement rose by 42%, the area planted to the grain fell by 35%, yields fell 6% to 1.8 tons per hectare (less than half of the world average), and total rice production plunged by 43%. As a result, rice imports have risen 20-fold, from 5,000 to more than 100,000 tons per year, at an annual cost of more than US$15 million.

Rice and wheat grown in rotation account for one-third of the cropping area of both grains in South Asia. Maintaining soil fertility and boosting yields in the rice-wheat system are vital to improving food security in this volatile region and to restoring peace in Afghanistan.

Imported rice accounts for some 30% of Afghan consumption of the grain, a figure roughly parallel to the one-third of the Afghan people who depend on international food aid.

The rice-wheat system is the focus of an ongoing ten-year scientific effort to ensure the continued productivity of the 13.5 million hectares of the Indo-Gangetic Plain where the system is practiced, as well as a further 10.5 million hectares in China.

"It's crucial that the rice-wheat farmers of South Asia continue to be able to harvest their crops and so feed the hundreds of millions of people who depend on them," warned IRRI Director General Ronald P. Cantrell. "And, today, it's a pressing need that the rice-wheat farmers of Afghanistan receive assistance in restoring the productivity of their farms."

In a global effort to assist rice-wheat farmers in South Asia, the national agricultural research and extension systems of Pakistan, India, Nepal and Bangladesh have joined forces with scientists from IRRI and other Future Harvest centers — including the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, the International Crops Research Institute for the Semi-Arid Tropics in India, the International Water Management Institute in Sri Lanka, and the International Potato Center in Peru — to form the Rice-Wheat Consortium for the Indo-Gangetic Plain. The consortium is funded by the Asian Development Bank, the government of The Netherlands, the Department for International Development (United Kingdom), the International Fund for Agricultural Development (Italy), the United States Agency for International Development, the government of Japan, and the Australian Centre for International Agricultural Research.

Sustainable strategies

The Rice-Wheat Consortium grew out of a joint project between IRRI and CIMMYT that started in 1990 as part of a major new effort to help rice-wheat farmers find sustainable new strategies and technologies to improve their lives. Fundamental to the project right from the start has been farmer participation to ensure that research is demand-driven. Equally important has been close collaboration among scientists from all the countries involved, including representatives of the often antagonistic neighbors India and Pakistan.

After the first phase of the project was completed in 1994, the project members established the Rice-Wheat Consortium, a major systemwide ecoregional initiative of the Consultative Group on International Agricultural Research (CGIAR), which includes the Future Harvest centers named above. The aim of the project has been to promote research that is fundamental to achieving enhanced productivity and the sustainability of the rice-wheat cropping system in South Asia.

Of particular note has been the project's success in getting farmers to move away from the high-input farming strategies introduced since the Green Revolution of the 1960s and 1970s toward more sustainable, profitable and environmentally friendly technologies.

In addition to this fundamental strategy, the consortium has adopted several other key principles. One of the first of these is the "precision farming" concept, which advances resource-conserving technologies that can increase crop productivity while at the same time reducing crop production costs, increasing farmers' income, and sustainably improving the quality of each farm's natural resources.

Jagdish Kumar Ladha, IRRI soil nutritionist and rice-wheat coordinator, said that years of intensive cropping in rice-wheat areas have seriously depleted the levels of soil nutrients available to future crops. "Additionally," he said, "the inappropriate use of fertilizers, which has been rampant in the region, has also adversely affected local soils."

He explained that precision farming teaches farmers about site-specific nutrient management and how to apply nitrogen, potassium and phosphorus in ways that avoid further nutrient depletion. "Every field is different, so farmers need to be quite specific about what each crop will need," Dr. Ladha stressed.

One of the great successes of the consortium has been the introduction of a simple tool known as the leaf color chart to help farmers determine the amount of nitrogen a rice or wheat crop needs. A recent study found that 175 farmers from India's Haryana State were successfully using the leaf color chart to cut their use of nitrogen fertilizer by up to 20%. Other precision-farming techniques, such as the deep placement of nitrogen tablets (or briquettes) and controlled-release fertilizers, helped further reduce farmers' application of nitrogenous fertilizer by up to 30%.

Water savings

Researchers have enjoyed success in helping grain growers cut their water use, in some cases achieving savings of up to 40%. This has been achieved by helping farmers introduce new strategies such as cultivating rice on raised irrigated beds rather than in puddled soils with standing water. They have also learned how to adapt rice production to leave the soil in suitable condition for the following wheat crop.

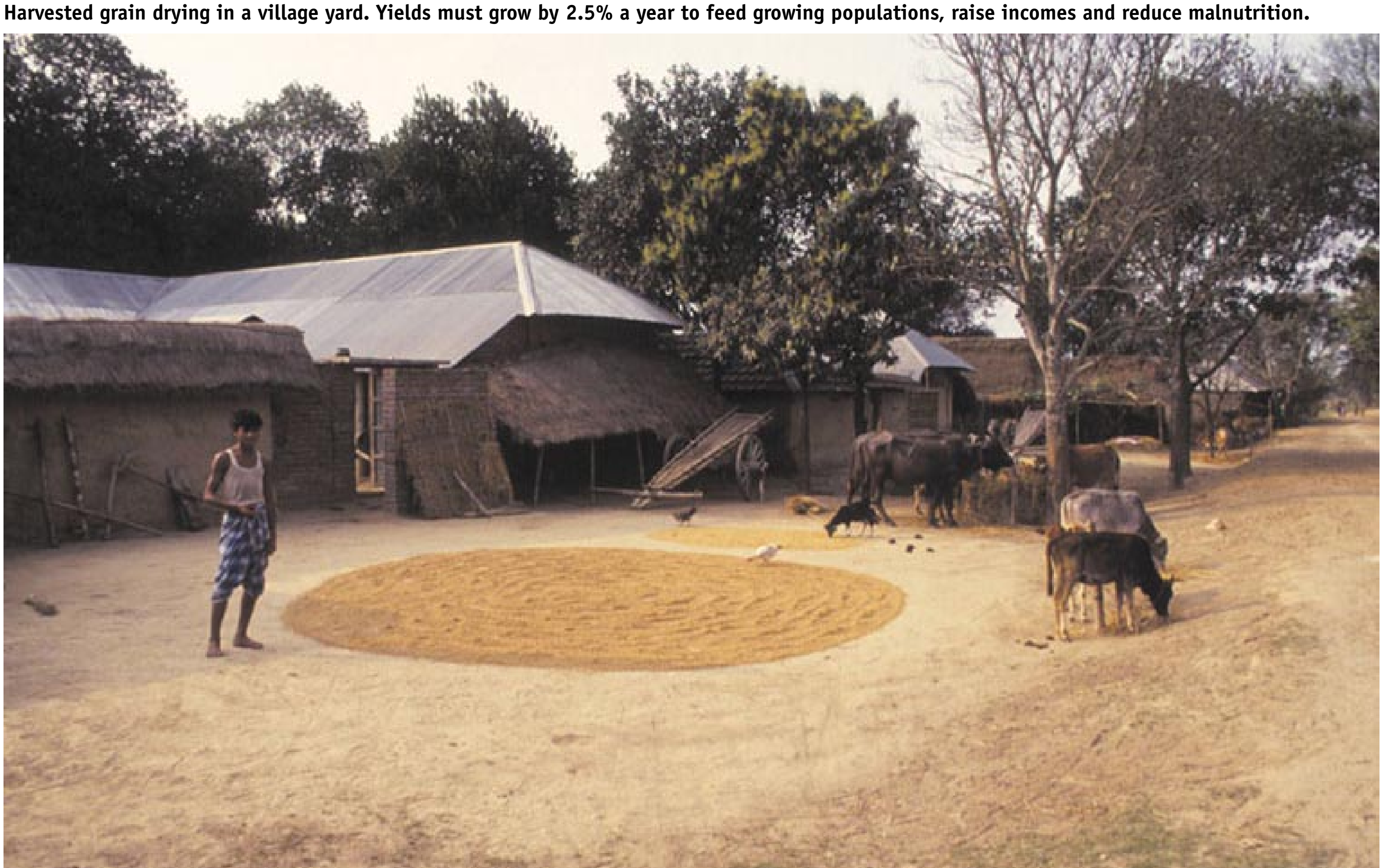
"The future sustainability of such an agricultural system strongly depends on maximizing input-use efficiency and reducing the cost of cultivation," explained Dr. Ladha, who added that the consortium research team is intensively monitoring the rice-wheat system. "Technological options for producing more rice and wheat through the more efficient use of resources such as water, labor, fertilizer and crop-protection agents are a major challenge that needs an integrated approach based on farmer participation.

"Other technologies being considered for integration into the rice-wheat system," added Dr. Ladha, "include land leveling for water savings [see *Laser Lite* on page 14], growing rice in unpuddled conditions for greater water and labor savings, alternative practices for weed and residue management for environmental protection and nutrient savings, and the conjunctive use of organic and inorganic nutrient sources for balanced nutrient management and fertilizer savings."

According to Raj K. Gupta, the consortium's regional facilitator, and Peter Hobbs, a CIMMYT agronomist, there is no doubt that the consortium is already one of the finest examples of collaboration in South Asia, providing clear evidence that countries in the region can work together to help their citizens improve their lives.

"The major challenge for the consortium members is to find new ways to ensure the food security of the region's millions of grain consumers while at the same time making rice-wheat farming more profitable," Dr. Hobbs explained. "While funding is a key constraint because many donor agencies are placing less emphasis on agriculture, we have to be optimistic."

Harvested grain drying in a village yard. Yields must grow by 2.5% a year to feed growing populations, raise incomes and reduce malnutrition.



Mekong harvests

Innovative research in the Mekong Delta of Vietnam promotes farmers' fair sharing of natural resources

Some 2,000 kilometers from its start on the Chinese border, Vietnam's fabled National Route 1 cuts flat and straight across the Mekong Delta province of Bac Lieu. Lining the two-lane highway are houses and shops, many of them perched on stilts over canals. Bicycles, motorbikes, pedestrians and buffalo carts hem the edges of the road, as buses, vans and trucks career down the middle, vying noisily for right-of-way.

The haphazard flow of traffic is routine. What makes this stretch of Route 1 unusual is how the road's century-old embankment is now being used to regulate the flow of water to improve agricultural productivity. The results are raising questions that challenge the entrenched assumptions and priorities that govern natural resource management. Beyond improving the lives of poor Vietnamese farmers today, the lessons being learned in Bac Lieu may help other regions cope with a future affected by global warming.

Farmland, like natural wilderness, is a complex ecosystem in which one altered feature can have far-reaching consequences. Managing natural resources in a way that ensures food security, promotes farmers' livelihood, and protects the environment is a delicate balancing act. Getting it right requires the active participation of farmers, agricultural scientists and extension workers, and government policymakers.

The Mekong Delta is the rice bowl of southern Vietnam, but until recently very few farmers in Bac Lieu — the second poorest province in the delta, with an annual per capita income of US$380 — managed to grow more than one rice crop per year. This was due to tidal inflows of seawater invading the canals that crisscross the province. Only during the rainy season, from June to October, are tidal forces overwhelmed by the outward flow of freshwater from the Mekong River, bringing water and soil salinity down to a level that allows rice cultivation.

The national government decided to remedy the situation by building a network of sluice gates that could be closed at high tide during the dry season to protect rice lands from saline intrusion. Exploiting the Route 1 embankment as an existing line of choke points parallel to the shoreline, though 15 km inland, the Quan Lo–Phung Hiep Water Control Project called for the phased construction of 13 large sluice gates and many smaller ones. Ten of the large gates have been completed since 1993, and as they have come on line, the saline-protected area has steadily expanded, allowing many thousands of rice farmers to grow two or even three crops per year.

"Between 1997 and 2000, our rice production rose from 800 to 1,200 kg per capita," reports Diep Chan Ben, the vice director of the provincial Department of Agriculture and Rural Development.

Clear benefit

This clear benefit to rice farmers has come, however, at the expense of their shrimp-farming neighbors — a significant minority of the half-million people who live within the boundaries of the saline-protection project — who were cut off from the supplies of brackish water they needed to fill their ponds.

Shrimp farming in Bac Lieu had recently become very profitable, following the introduction of large varieties raised for export. It is also a gamble — a high-stakes investment always in danger of being wiped out by disease. As elsewhere in Southeast Asia, divergent priorities have long pitted rice and shrimp farmers against each other, echoing the rivalry in the late 19th century between herders and cultivators on the Great Plains of North America.

"Shrimp is too risky to try," says 42-year-old Nguyen Van Mao, a successful rice farmer. "I grew up here and saw neighbors lose their farms and houses through shrimp failure. Rice production may have smaller profit margins, but it's stable enough to keep my children in school."

Shrimp farming became very profitable with the introduction of large varieties raised for export (*inset below, shown with small, native shrimp*), just as protection against saltwater intrusion made possible multiple rice cropping and bigger harvests (*opposite*). But rice requires freshwater, shrimp brackish water. The question became how best to manage water resources to balance these competing demands.

Mao is fortunate that his cautious approach to farming is a good match for the soil of his medium-sized holding of 3.9 hectares, which remains fertile under the double cropping of rice that saline protection now makes possible. Many of his neighbors aren't as lucky because their soil is potentially acidic.

A comprehensive study led by IRRI and financed by Britain's Department for International Development highlights the problem. Duong Van Ni, project coordinator with the Mekong Delta Farming Systems R&D Institute of Can Tho University, one of IRRI's local collaborators on the Bac Lieu Livelihood Project, explains that potentially acidic soil becomes actually acidic when it dries out too much. The recommended use for such land in Bac Lieu is to grow rice in the rainy season and shrimp in the dry, to reduce land-preparation time and keep the soil wet during the dry season. Aside from providing basic food security for farmers — and perhaps a small surplus to sell — the single rice crop leaves straw to feed the blue algae that are the main food for the following shrimp crop.

Acidic soils are concentrated in newly protected "downstream" areas of Bac Lieu. At the urging of shrimp farmers, officials began approving the occasional opening of some sluice gates to let saltwater flow into these areas. The decision reflected rethinking of the government's priorities away from the determined pursuit of higher rice production toward a more complex weighing of alternatives.

Competing demands

The question then became how best to manage the sluice gates to balance competing demands: the shrimp farmers' need for brackish water in the dry season, the rice farmers' desire to retain the benefits of year-round saline protection, and the imperative to prevent the accumulation of pollutants in the waterways, to protect the inland fisheries vital to the poorest residents, especially the landless.

Mao expected the mitigation of saline protection to erode some of his newly won 250% gain in rice productivity, as salt intrusion would likely affect the yield of his second, September–December rice crop. At the same time, he strives to be a good neighbor and supports the balanced sharing of natural resources. He is confident that he can minimize his losses by planning ahead, but only if a fixed schedule for opening the sluice gates is publicized in advance.

Determining an optimum gate-management regime is a task of daunting complexity. IRRI water management scientist To Phuc Tuong,

Truong Van Phuong (*left*) stands before Phosingh Gate in the Gia Rai District of Bac Lieu, which he operates according to a schedule devised through hydraulic modeling to allow the bountiful harvests of intensive rice farming in some land-use zones (*above*) and highly profitable shrimp farming in other zones, while protecting the inland fisheries (*right*) that are vital to the poorest residents, especially the landless.

project manager of the Bac Lieu Livelihood Project, explains that researchers must understand the water-quality requirements of rice and shrimp farmers at different times of the year, model how various gate-opening scenarios will affect water quality — particularly salinity — at different places and times, and determine which scenarios can satisfy farmers' requirements.

More broadly, gauging the socio-economic impact of policy decisions entails surveying existing patterns of how people make a living and how well they do, estimating the effect of various proposed policies on the livelihoods of different groups, and predicting how people will respond to change, in particular how they may choose to use their land differently. The complexity of the problem is compounded in that rice-farming families typically grow other crops in addition to rice and often draw income from sideline occupations away from the farm.

Useful combinations

In partnership with farmers, researchers test the sustainability of new and existing agricultural technologies. They compare the performance of traditional and improved rice varieties under local conditions, seeking useful combinations of salinity and acidity tolerance, pest and disease resistance, yield potential, and grain quality and marketability. Similarly, they assess customary and innovative approaches to such cultural practices as seeding, watering, fertilizing, weeding, controlling pests and diseases, and harvesting. The IRRI-led team also aims to help rice-shrimp farmers understand how water salinity and acidity affect shrimp and how to avoid crop-devastating disease.

The Bac Lieu Livelihood Project marks a trend in agricultural research toward a holistic and integrated approach to using natural resources, dubbed ecoregional integrated natural resource management (INRM). This approach adopts a problem-oriented framework for tackling agricultural challenges that deploys the full range of scientific assets that can be brought to bear, from laboratory-bound disciplines such as biotechnology to such "soft sciences" as sociology. By working closely with policymakers and farmers, and by facilitating a mutual learning process, it strives to address issues linking agriculture and natural resource management beyond the field scale. It also aims to bridge the gap between this bottom-up approach and the top-down view of planners and policymakers.

Researchers hope and expect that the lessons learned in the Mekong Delta ecoregion will be applicable in other parts of South and Southeast Asia, where two million hectares of tidal-saline rice lands are farmed by people who are among the poorest and most food-insecure in the world. Fears that global warming may cause sea levels to rise, pushing saline intrusion inland, lend urgency to the task.

In an up-and-coming field such as ecoregional INRM, research methods can be as eye-catching as the results they produce. One valuable tool for interdisciplinary study is mapping with geographic information systems (GIS), which allows scientists to layer wide-ranging data into compact, analyzable packages (see *Bac Lieu Livelihood Project* on the inside back cover).

"GIS is a computer-based technology for integrating maps and data, both biophysical and socio-economic, from various sources," explains Suan Pheng Kam, IRRI's GIS specialist. "In this project, we use a combination of satellite images, existing statistical data, and field interviews to analyze and better understand how the water-control scheme affects land use and farmers' livelihoods in the study area. GIS also makes it easier for scientists to present the results of complex water-flow and water-quality models to local authorities, so that they understand the implications of their decisions for what farmers can do with their land and water resources."

The project aims to help farmers understand how water salinity and acidity affect shrimp and how to avoid crop-devastating disease. Nguyen Hoang Xiem (*above*) observes as one of his ponds is tested for acidity — a particular concern because his farm is blighted by soil that is actually acidic, not just potentially so. Dr. Ni, the Can Tho University researcher and project coordinator (*below left, with Mr. Xiem and his family*), reports that shrimp farming is not recommended on actually acidic soil due to the high cost of dosing ponds with lime (which consumes a quarter of what Mr. Xiem can hope to earn) and the high risk of crop failure. The ambitious young farmer nevertheless switched recently from growing rice alone to alternating rice with shrimp, in the hope of making enough money in two years to replace his nipa-thatch hut with a concrete house.

In addition to modeling changes in water quality and monitoring land-use conversion, IRRI performs the central role of coordinating the activities of various collaborators in the Bac Lieu Livelihood Project.

The good news for Nguyen Van Mao is that researchers submitted their findings to local officials, and together they delineated land-use zones and developed a hydraulic model to determine sluice operation for controlling saltwater inflow in line with each zone's soil conditions and water-quality requirements. This should allow the rice farmer to adjust his cropping schedule with confidence.

But the scientists' work is far from done. For at least the next two years, they will continue monitoring water and soil quality, helping to fine-tune management of the Quan Lo–Phung Hiep Water Control Project, and working with the farmers of Bac Lieu to lift them out of poverty.

This feature was published in the March 2002 issue of The World & I *magazine as the third of six essays in the series* Struggle for Development. *This abridged version is republished in* Rice Today *with permission from* The World & I, *a publication of The Washington Times Corporation.*

FUTURE[SM] HARVEST

News from IRRI's sister Future Harvest centers in the Consultative Group on International Agricultural Research

First East Asian DG at CIMMYT

The International Maize and Wheat Improvement Center (CIMMYT) announced in March the appointment of Masa Iwanaga as its new director general. Dr. Iwanaga, a Japanese national and the first East Asian citizen to become a director of a CGIAR center, has more than two decades of research and management experience in international development. His association with the research centers supported by the CGIAR began with the International Potato Center in Peru, where he was a cytogeneticist. Subsequently he was head of the Genetic Resources Unit at the International Center for Tropical Agriculture in Colombia and deputy director general for Programs at the International Plant Genetic Resources Institute in Italy.

Most recently, Dr. Iwanaga was director of the Biological Resources Division of the Japan International Research Center for Agricultural Sciences. He was replaced there by **Ryoichi Ikeda**, former director of the Rice Research Division of Japan's National Institute of Crop Science. **Tokio Imbe** moved up from the Rice Breeding Laboratory to replace Dr. Ikeda. Dr. Ikeda was a plant breeder at IRRI in 1988-93, as was Dr. Imbe in 1993-98.

New and noteworthy

Prabhu Pingali was slated in September to take up his new position as director of the Economic Analysis Division of the **Food and Agriculture Organization** (FAO) in Rome. The division is the focal point for all FAO economic research and policy analysis on food security and environmental sustainability. Dr. Pingali was director of the Economics Program at the International Maize and Wheat Improvement Center (CIMMYT) and formerly an IRRI economist. **Michael Morris** took over as interim director of CIMMYT's Economics Program.

Paul Harding is now executive secretary of the **European Initiative on Agricultural Research for Development**, the European group of donors supporting agricultural research and development conducted by the CGIAR centers, the Global Forum on Agricultural Research, regional and subregional research organizations, and the national agricultural research and extension systems. Dr. Harding is based in Brussels and hosted by the European Commission.

Meine van Noordwijk was confirmed in May as the Los Baños-based Southeast Asia regional coordinator for the **International Centre for Research in Agroforestry** (ICRAF). A Dutch national, Dr. van Noordwijk joined ICRAF in 1993 and became principal soil scientist in 1997, with particular attention to developing and refining agroforestry alternatives to slash-and-burn agriculture.

Info Finder is a unique searchable website jointly launched recently by the CGIAR and the Food and Agriculture Organization (FAO). The site, which can be reached from the home page of either the CGIAR (www.cgiar.org) or the FAO (www.fao.org), allows users to search online material from Future Harvest, the CGIAR and the FAO's World Agricultural Information Center (WAICENT) all at once.

WARDA's Board of Trustees reported in April that an intensive two-month investigation had "found no case or evidence of fraud or corruption" that supports anonymous allegations made to the World Bank against the West Africa Rice Development Association and its director general.

Agroforestry pioneer wins 2002 World Food Prize

Pedro Sanchez, director general of the International Centre for Research in Agroforestry from 1991 to last year, won the $250,000 World Food Prize for 2002. The Cuban-born soil scientist was selected for his contributions to reducing hunger and malnutrition in the developing world by transforming depleted tropical soils into productive agricultural lands.

As the leader of the North Carolina State University Rice Research Program in the 1970s, Dr. Sanchez helped Peru achieve self-sufficiency in rice. He then developed a comprehensive approach to soil management that enabled 30 million hectares of marginal Brazilian land to be brought into production — the single largest increase in arable land in the last half-century.

Most recently, Dr. Sanchez developed and promoted agroforestry practices that have helped smallholder farmers in Africa and Southeast Asia revive exhausted soils. Recognizing his enormous contribution, U.N. Secretary-General Kofi Annan appointed Dr. Sanchez chair of the Taskforce on Hunger of the U.N. Global Millennium Development Project.

He will receive his award in October.

New head for Future Harvest

Judith Symonds became the executive director of Future Harvest in mid-April. A specialist in international issues advocacy, agricultural policy and development, Ms. Symonds comes to the position with over 25 years of combined strategy, communication, management and fund-raising experience. She has served as president of the Foundation for the Development of Polish Agriculture, director for Europe of the marketing and communications agency Ruder Finn, representative of The German Marshall Fund of the U.S. in France and advisor to the Agriculture Directorate of the Organization for Economic Cooperation and Development. Ms. Symonds replaces Barbara Rose, who left to devote more time to her family business.

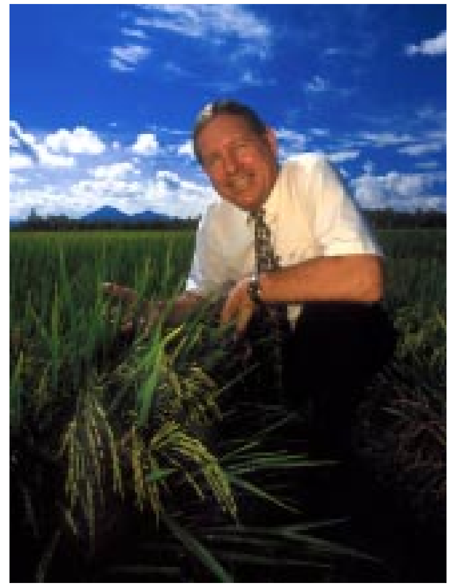
IRRI director general renews 5-year contract

Ronald P. Cantrell accepted the IRRI Board of Trustees' offer of a second five-year contract as director general, to the end of May 2007.

"In addition to his overall management responsibilities, Dr. Cantrell will focus especially on the challenge of ensuring the institute's continued financial stability during a time of ongoing reductions in donor funding," explained Board Chair Angeline Kamba.

Dr. Cantrell's career in international agricultural research began in 1981, when he headed the Purdue University Farming Systems Team in Ouagadougou, Burkina Faso (formerly Upper Volta), in West Africa. In 1984, he took over as director of the Maize Program at the International Maize and Wheat Improvement Center in Mexico, where he decentralized the germplasm development system to better develop and capitalize on collaborative programs with national agricultural research systems. In 1990, he became a professor of plant breeding and head of the Agronomy Department at Iowa State University, where he strengthened the links between international centers and American land-grant colleges and universities.

Dr. Cantrell was named a Fellow of the Crop Science Society of America in 1993 and a Fellow of the American Society of Agronomy in 1994. He received the International Service in Crop Science Award in 1994 and, in 1998, was elected president of the Crop Science Society of America.



Honors for IRRI scientists

Sant Singh Virmani, plant breeder and deputy head of Plant Breeding, Genetics and Biochemistry, will receive this year's International Service in Crop Science Award from the Crop Science Society of America at its annual meeting in November. During the past 23 years at IRRI, Dr. Virmani has provided and shared convincing evidence of the potential for irrigated hybrid rice in the tropics, and hybrid rice varieties are now grown commercially in Vietnam, India, Philippines, Bangladesh, and Myanmar. In May, during a hybrid rice symposium in Vietnam, Dr. Virmani received the Agriculture and Rural Development Medal for his contribution to the advancement of hybrid rice technology in that country.

Dr. Virmani (*second from right*), Professor Yuan Long-ping (*right*), and Dat Van Tran (*partly hidden*) are honored by Nguyen Cong Tan (*second from left*), the deputy prime minister of Vietnam, for their contributions to the advancement of hybrid rice technology in Vietnam.

Tom Mew, IRRI plant pathologist and head of the Entomology and Plant Pathology Division, was named a Fellow of the American Phytopathological Society at a ceremony in Milwaukee, Wisconsin, in July. Dr. Mew's achievements have spanned nearly three decades in plant pathology, breeding and agronomy, balancing scientific depth with practical approaches to disease control that benefit rice growers throughout Asia. His promotion of pathology research programs in the developing world has produced a cadre of plant pathologists who now lead worldwide efforts in crop protection for rice.

J.K. Ladha, IRRI soil-fertility and plant-nutrition specialist, will become a Fellow of the American Society of Agronomy at its annual meeting in November. Dr. Ladha's research focuses on developing and implementing farm-nutrient management and crop-establishment strategies that minimize environmental effects and maximize farmers' income. Dr. Ladha chairs the Commission of Soil Biology of the International Union of Soil Science.

Darshan Brar, IRRI plant breeder, was named an Honorary Fellow of the Crop Science Society of the Philippines for 2002 at the society's annual conference in April. Dr. Brar is recognized for his pioneering work on wide hybridization of rice. He has introgressed genes from wild species for resistance to such diseases as bacterial blight, brown planthopper, blast and tungro.

Khush Hall is tribute to retired plant breeder

Gurdev S. Khush Hall is the new name for the former Collaborators' Center building on the IRRI research campus. Angeline Kamba, chair of the IRRI Board of Trustees, unveiled the commemorative marker during a ceremony in April, saying that Dr. Khush had, "over a period of 34 years, carved a name for himself in the annals of plant breeding and is a monument in his own lifetime."

Also in April, Malacañang Palace announced a Philippine presidential citation for Dr. Khush, citing "his invaluable contributions in helping the Filipino people in producing more food by increasing rice production in the country through the use of modern rice varieties." In March, Indonesian President Megawati Sukarnoputri presented Dr. Khush with a certificate of recognition for his dedication to improving rice production, as Bungaran Saragih (*left in photo*), the Indonesian minister of Agriculture, looked on.

In May, Dr. Khush was elected as a foreign member of the Chinese Academy of Sciences and, in June, as a foreign academician of the Russian Academy of Agricultural Sciences.

Keeping up with IRRI staff

Kwame Akuffo-Akoto was scheduled to start as IRRI's new treasurer and director for Finance in September. Born in Ghana, Mr. Akuffo-Akoto was director for Finance and Administration at the International Crops Research Institute for the Semi-Arid Tropics in India from 1996 to 2002 and earlier exercised similar functions at the West Africa Rice Development Association in Côte d'Ivoire. A member of the Board of Trustees of the Association of International Agricultural Research Centers, he replaces **Gordon MacNeil**, who returned to the World Bank in Washington, D.C.

Nigel Ruaraidh Sackville Hamilton assumed his duties as the new head of IRRI's Genetic Resources Center in August. Dr. Sackville Hamilton was previously the biodiversity group leader and head of the Genetic Resources Unit at the Institute of Grassland and Environmental Research in his native United Kingdom.

Roland Buresh of Crop, Soil and Water Sciences became the new program leader for Program 2 (Enhancing productivity and sustainability of favorable environments) in May. Dr. Buresh also assumed the role of project team leader of Project 6 (Irrigated Rice Research Consortium, or IRRC) and serves as coordinator of the IRRC.

Suan Pheng Kam of the Social Sciences Division replaced Dr. Buresh as acting project team leader for Project 8 (Natural resource management for rainfed lowland and upland rice ecosystems). Dr. Kam continues to serve as project team leader for Project 11 (Enhancing ecological sustainability and improving livelihoods through ecoregional approaches to integrated natural resource management).

Tanguy Lafarge, seconded from the Centre de Coopération Internationale en Recherche Agronomique pour le Développement, joined Crop, Soil and Water Sciences in July to work on improving yields in irrigated rice.

Robin D. Graham, plant nutritionist from the University of Adelaide, Australia, joined Plant Breeding, Genetics and Biochemistry in June for a six-month stint as an international research fellow to help build IRRI's micronutrient expertise.

Nobuhiko Fuwa joined IRRI's Social Sciences Division as an international research fellow in August.

Kaung Zan passed away on 22 December 2001 in Yangon. Dr. Zan served on the Board of Trustees in 1975-77 and as liaison scientist for Africa in 1978-85.

K.L. Heong received a DSc from Imperial College, the highest academic degree awarded by the University of London, for research over the last 12 years on integrating ecology and sociology in pest management. Dr. Heong is the first scientist to earn a higher doctorate degree based on research conducted at IRRI.

Trustee wins Charles A. Black Award

The Council for Agricultural Science and Technology (CAST) in March awarded Calvin Qualset, IRRI Board of Trustees member since 1999, the 2002 Charles A. Black Award for his life's work in germplasm preservation and enhancement. A Nebraska native, Dr. Qualset is founding director of the Genetic Resources Conservation Program at the University of California-Davis, where he is also professor emeritus and research professor. His research areas include crop breeding, genetics and evolution, conservation of plant genetic resources, and biotechnology policy.

Dr. Qualset has served as chair of the Section on Agriculture, Food and Renewable Natural Resources for the American Association for the Advancement of Science (AAAS), president of the American Society of Agronomy (ASA) and president of the Crop Science Society of America (CSSA). He has been honored as a fellow by the AAAS, ASA and CSSA. He was a Fulbright Senior Research Scholar and Fulbright Senior Research Lecturer. Dr. Qualset was a member of the task force that prepared the CAST issue paper *Applications of biotechnology to crops: benefits and risks.*

Collaborators on the move

Peter Core is the new director of the Australian Centre for International Agricultural Research (ACIAR), commencing his five-year term in July. He was previously managing director of the Rural Industries Research and Development Corporation (RIRDC) in Canberra. ACIAR commissions projects to assist developing countries by mobilizing Australia's agricultural research expertise. Mr. Core, who has a background in agricultural economics and a reputation for strong and strategic leadership, succeeded **Robert Clements**, who became director in 1995 and is now executive director of the Crawford Fund.

Badaruddin Soomro was appointed chairman of the Pakistan Agricultural Research Council (PARC) in April. At PARC, Dr. Soomro has been chief scientist II and member of Crop Sciences, and he earlier served Sindh Province as secretary of the Department of Agriculture (1997-98), director general of Agricultural Extension (1992-95), managing director of the Sindh Seed Corporation (1991-92), and director general of Agricultural Research (1989-91). He has more than 40 publications to his credit and in 1990 received from the Pakistani president the title Tamagha-I-Imtiaz for his research achievements.

Rajendra S. Paroda has stepped down as chairman of the Global Forum on Agricultural Research, a position he has filled since 1998, to become coordinator of the Regional Program for Central Asia and the Caucasus of the International Center for Agricultural Research in the Dry Areas. Dr. Paroda served as a member of IRRI's Board of Trustees from 1990 to 1993.

CGIAR ANNUAL MEETING IN MANILA

The annual general meeting (AGM) of the Consultative Group on International Agricultural Research (CGIAR) will take place at the Makati Shangri-La Hotel in Manila, Philippines, on 30 October-1 November. Attended by representatives of the CGIAR centers and donor members, the AGM includes stakeholders' and business meetings, science awards, and the Crawford Lecture on an agricultural topic of global significance. On 28-29 October, the AGM will kick off in nearby Los Baños with a Philippines-IRRI program featuring exhibits, a symposium and a field tour.

1ST INTERNATIONAL RICE CONGRESS

IRRI, the Chinese Academy of Engineering, the Chinese Academy of Agricultural Sciences, and the State Development and Planning Commission, China, are organizing the inaugural International Rice Congress 2002, to be held on 16-20 September at the China International Hi-Tech Convention and Exhibition Center in Beijing. With the theme "Innovation, impact, and livelihoods," the congress will feature the 24th International Rice Research Conference (the latest scientific breakthroughs, 16-19 September), the World Rice Commerce Conference (authoritative rice trade analysis and commercial information, 17-18 September), and the International Rice Technology and Cultural Exhibition (the latest technologies and the best rice culture, 16-18 September). Contact T.W. Mew, congress chair, at T.Mew@cgiar.org.

WILD RICE IN KATHMANDU

Green Energy Mission/Nepal will conduct the International Conference on Wild Rice in Kathmandu, Nepal, on 21-23 October 2002, with the theme "Conservation and utilization of wild rice for the food security of the world." Following the conference, there will be a wild rice field trip to the Lumbini area on 24-27 October. Contact Gyan Lal Shrestha, conference chair, at gyanlal@hotmail.com or gemnepal@info.com.np.

IPR WORKSHOPS

Visit www.bioDevelopments.org or send an email to info@bioDevelopments.org for details.

Intellectual Property Rights in International Agricultural Research and Development: Strategies and Applications. An intensive executive workshop focused on practical applications and implications in Asia. Manila, Philippines, 10-14 November 2002. Same program for Africa. Nairobi, Kenya, 8-12 December 2002. By Dodds & Associates, attorney at law, Washington, D.C., and bioDevelopments-International Institute, Ithaca, New York.

Intellectual Property Management in Agriculture. An intensive workshop for scientists, research managers, licensing/technology transfer officers and policymakers. Sharm el Sheik, Egypt, 15-20 December 2002. By SWIFTT at Cornell University, Ithaca, New York, Dodds & Associates, attorney at law, Washington, D.C., and bioDevelopments-International Institute, Ithaca, New York.

Conferences, meetings and workshops

Date	Event	Venue	Contact
16-20 Sep	International Rice Congress	Beijing, China	T.Mew@cgiar.org http://www.irri.org/irc2002/index.htm
18-20 Sep	World Genomics Symposium and Exposition	Atlantic City, New Jersey, USA	http://www.world-genomics.com
22-24 Sep	World Fertilizer Conference	San Francisco, California, USA	vbrown@tfi.org www.tfi.org
26 Sep	Protect Knowledge to Feed the World? Application of intellectual property rights in international agriculture today and tomorrow	Muri-bei-Bern, Switzerland	http://www.infoagrar.ch/ipr-symposium
29 Sep-12 Oct	Training Workshop on Rice Technology Transfer System in Asia	Suweon, South Korea	M.Bell@cgiar.org sdaegeun@rda.go.kr
5-7 Oct	Irrigation Water Conservation — Opportunities and Limitations, A Water Management Seminar	Sacramento, California, USA	U.S. Committee on Irrigation and Drainage, 1616 17th Street, Suite 483, Denver, CO 80202, USA
9-11 Oct	Conference on Agricultural and Natural Resource Management Research for Development	Witzenhausen, Germany	info@tropentag.de http://www.tropentag.de http://www.atsaf.de
11 Oct	Soil Fertility — A Major Challenge for Development in the 21st Century	Zollikofen, Switzerland	Alex.Eigenmann@shl.bfh.ch
21-27 Oct	International Conference on Wild Rice	Kathmandu, Nepal	gyanlal@hotmail.com gemnepal@info.com.np
Nov	Brighton Crop Protection Conference 2002	Brighton, UK	eventorg@event-org.com http://www.bcpc.org
11-14 Nov	Crop Science Society of America Annual Meeting	Indianapolis, Indiana, USA	http://www.asa-cssa-sssa.org/calendar
17-20 Nov	Entomological Society of America Annual Meeting	Fort Lauderdale, Florida, USA	esa@entsoc.org http://www.entsoc.org
18-21 Nov	Pests and Diseases 2002		md@bcpc.org
2003			
2-8 Feb	8th International Congress of Plant Pathology	Christchurch, New Zealand	icpp2003@lincoln.ac.nz http://www.lincoln.ac.nz/pdg/icpp2003/frames
9-11 Feb	2003 Fertilizer Marketing Business Meeting	San Antonio, Texas, USA	vbrown@tfi.org http://www.tfi.org
10-13 Mar	Tercera Conferencia Internacional de Arroz de Clima Templado	Punta del Este, Uruguay	congresos@rohrsa.com http://www.congresos-rohr.com/arroz
16-21 Jun	7th International Congress of Plant Molecular Biology	Barcelona, Spain	congress@aopc.es http://www.ispmb2003.com/
6-11 Jul	15th International Plant Protection Congress	Beijing, China	ippc2003@ipmchina.net http://www.ipmchina.cn.net/ippc/index.htm
9-13 Aug	American Phytopathological Society Annual Meeting	Charlotte, North Carolina, USA	aps@scisoc.org http://www.scisoc.org

2003 IRRI group training courses (tentative listing)

Course	Duration (weeks)	Course coordinator(s)	Approximate schedule
Integrated Nutrient Management	2	R Buresh	Feb or Mar
Rice Production Training (2 offerings)	2	V Bala	Feb, Aug
Principles & Practices: Farm Management	3	J Rickman	Mar
Integrated Pest Management	3	K Heong	Apr
Rodent Management	3	G Singleton/K Heong	May or Jun
Water Management (Philippines only)	1	B Bouman	Jul or Sep
Genetic Engineering	1	S Datta	May
Rice Breeding	2	G Atlin	Aug
Intellectual Property Rights	TBA	T Wai	TBA
Genomics/Bioinformatics	TBA	H Leung	TBA
Scientific Writing/Presentation Skills	2	M Arboleda	May
English as a Second Language	varies	M Arboleda	various
eLearning for Development	2	A Atkinson	TBA
Biometrics (3 different courses)	1	G McLaren	May-Aug

The following in-country courses can be given based on demand, instructor availability, and available resources: Seed Technology, Grain Quality/Quantity, Research Management/Project Management, Application Safety, Hybrids, Land Leveling, Leaf Color Chart/Nutrient Management, Needs and Opportunities Assessment/Participatory Rural Appraisal, Multi-Agent Systems.
TBA: To be arranged. Schedules are subject to change. For inquiries: IRRI-Training@cgiar.org; Fax: (63-2) 891-1292; Mailing address: DAPO Box 7777, Metro Manila, Philippines. Visit http://www.training.irri.org for updates.

Essential food for the poor

The new edition of the Rice Almanac is a cornucopia of rice facts. See the ad on the back cover.

Rice growers and consumers constitute the bulk of the world's population that still lives in poverty

Approximately 70% of the world's 1.3 billion poor people live in Asia, where rice is the staple food. To some extent, this reflects Asia's large population, but even in relative terms malnutrition appears to affect a substantially larger share of the population in South Asia than in Africa. For these people, rice is the most important commodity in their daily lives. In countries such as Bangladesh, Vietnam and Myanmar, the average citizen consumes 150–200 kg annually, which accounts for two-thirds or more of caloric intake and approximately 60% of daily protein consumption (Table 1). Even in relatively wealthier countries such as Thailand and Indonesia, rice still accounts for nearly 50% of calories and one-third or more of protein.

Rice is also the most important crop to millions of small farmers who grow it on millions of hectares throughout the region, and to the many landless workers who derive income from working on these farms.

At low levels of income, when meeting energy needs is a serious concern, people tend to eat coarse grains and root crops such as cassava and sweet potato. At that lowest stage of economic development, rice is considered a luxury commodity. With increasing income, demand shifts from coarse grains and root crops to rice. At high levels of income, rice becomes an inferior commodity, and consumers prefer diverse foods with more protein and vitamins, such as vegetables, bread, fish and meat.

Growing urbanization that accompanies economic growth leads to changes in food habits and the practice of eating away from home, which further reduces per capita rice consumption. The more industrialized countries of Asia, such as the Republic of Korea, Japan, Taiwan (China), Malaysia and Thailand, have begun to experience a decline in per capita rice consumption after reaching high levels several decades earlier (Fig. 1). But these high- and middle-income countries account for less than 10% of total rice consumption in Asia.

The annual income threshold at which consumers start substituting higher quality and more varied foods for rice is estimated at around US$1,500. This income threshold has not yet been reached in Bangladesh, China, India, Indonesia, Myanmar, the Philippines and Vietnam. These countries account for more than 80% of total rice consumption and are going to dominate the future growth in demand.

Table 1. Rice consumption, caloric intake, caloric intake from rice, percent of calories from rice, percent of protein from rice, and gross national income per capita

Country	Milled rice consumption (kg/capita/year) 1999	Total calories/ capita/ day 1999	Rice calories/ capita/ day 1999	% calories from rice 1999	% protein from rice 1999	GNI per capita, US$ Atlas method, World Bank 2000
Myanmar	211	2,803	2,050	73	68	–
Laos	171	2,152	1,506	70	65	290
Vietnam	170	2,564	1,676	65	57	390
Bangladesh	168	2,201	1,676	76	65	370
Cambodia	165	2,000	1,527	76	70	260
Indonesia	154	2,931	1,525	52	44	570
Thailand	101	2,411	1,004	42	34	2,000
Philippines	100	2,357	974	41	31	1,040
Korea, Rep. of	94	2,917	1,021	35	20	8,910
Madagascar	91	1,994	917	46	43	250
China	90	3,045	911	30	19	840
Malaysia	88	2,969	861	29	19	3,380
India	74	2,417	736	30	24	450
Japan	60	2,782	642	23	12	35,620
Egypt	41	3,323	426	13	9	1,490
Brazil	40	3,012	409	14	10	3,580
Nigeria	23	2,833	237	8	8	260
Pakistan	15	2,462	150	6	5	440
USA	9	3,754	94	3	2	34,100
Turkey	7	3,469	65	2	1	3,100
Mexico	6	3,168	61	2	1	5,070
WORLD	58	2,808	577	21	15	–

Sources: FAO online database (FAO update 31 May 2001); World Development Report (2002), World Bank.

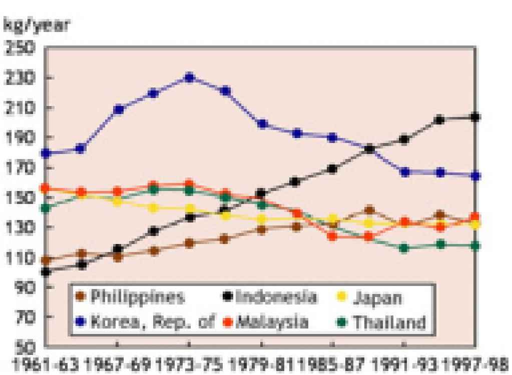


Fig. 1. Trend in per capita cereal consumption, selected Asian countries, 1961-98.

Adapted from Maclean JL, Dawe DC, Hardy B, Hettel GP, editors. 2002. Rice Almanac, Third Edition. *Wallingford (UK): CABI Publishing and Los Baños (Philippines): International Rice Research Institute. 253 p.*

ROLAND J. BURESH
Soil Scientist

Lessons learned in the long term

The most intensively cropped experimental site in Asia began four decades ago largely as a demonstration plot conveniently close to IRRI's administrative buildings. Researchers recognized its potential as an outdoor laboratory, and today the Long-Term Continuous Cropping Experiment (LTCCE) is a treasure for researching the sustainable management of intensive irrigated rice ecosystems.

Between the first planting on 18 February 1963 and the middle of 2002, the LTCCE produced 115 rice crops on its single hectare — two crops annually until 1968, then three crops per year using short-duration modern varieties. The LTCCE is thus a prototype of the irrigated rice ecosystems that have spread across Asia and become increasingly vital to food security. Irrigated fields producing two or three crops of rice per year now account for more than 40% of world rice production. One and a half billion rice farmers and consumers depend on their sustainable productivity. The LTCCE provides early insights into the long-term effects of intensive cropping on these ecosystems and how best to maintain their resource base and productivity.

> 1.5 billion rice farmers and consumers depend on the sustainable productivity of irrigated fields producing two or three crops of rice per year

We manage the LTCCE to achieve high and stable yields on a sustainable basis, with annual grain production for the three rice crops reaching 17 t/ha. We examine high-yielding varieties and elite breeding lines in combination with optimal nitrogen (N) fertilizer and crop management. We research the soil's microbial dynamics, organic matter, carbon sequestration, and chemical and biological changes, as well as cultivar micronutrient content, aquatic arthropods, and interactions between N fertilizer and rice diseases.

Through the LTCCE, we have learned that high rice yields remain attainable after intensive cropping for more than 30 years. A rice yield of 8.9 t/ha in the 2002 dry season with optimal N fertilizer management was the fifth highest to date in the history of the experiment. It was made possible by favorable climatic conditions. Climate, particularly solar radiation, is the dominant factor affecting long-term yield trends when N and crop management are optimized for high yield.

Much of the N in high-yielding rice comes from indigenous soil organic matter and biological N_2 fixation, but supplemental N from fertilizer is essential. The optimal amount is directly related to plant need, which rises in high-yielding seasons. With the "best" N fertilizer practice historically used in the LTCCE (and typically recommended to Asian rice farmers), the rate of N fertilizer for a given season remains constant from year to year. We have learned, however, that rice yields can be further improved with need-based management. This means applying N to "feed" rice only when it is "hungry" because the N content in plant tissue has fallen to a critical level.

Farmers can quickly and easily gauge this level with simple tools such as the chlorophyll meter or the inexpensive leaf color chart. In the 2001 and 2002 dry seasons, need-based N management guided by the leaf color chart resulted in higher rice yields than did the "best" N practice. We achieved this yield improvement by better adjusting N fertilizer use to the growing season and climatic conditions — without decreasing the fertilizer's effectiveness (yield per amount added). This demonstrates the potential for knowledge-based N management practices to further boost yield, largely through adjusting crop management to seasonal and site-specific conditions.

We have learned that intensive rice ecosystems can maintain soil organic matter, levels of which in the LTCCE have actually *increased* slightly (5–10%) in the past 15 years. This is remarkable because we remove all aboveground crop residues. Aquatic organisms and biological processes unique to submerged soils ensure sustained soil organic matter and sequestration of soil carbon.

We have learned that the capacity of irrigated rice ecosystems to supply indigenous N to rice can be sustained under intensive cropping. The yield in LTCCE plots not receiving N fertilizer has remained constant for the past 25 years. In this ecosystem with relatively high inherent soil fertility, biological N_2 fixation and N released from soil organic matter continue to supply a steady 50–60% of the N needed by high-yielding rice.

In sum, well-managed irrigated rice ecosystems are masterpieces of ecological vitality and sustained productivity. Soil submergence weaves an array of biological, chemical and physical processes that make these ecosystems unique in agriculture. Our understanding of their ecological marvels, which the LTCCE continues to expand, helps us to refine natural resource management to further enhance productivity and sustainability in an environment-friendly fashion.

3.5 billion malnourished

"Hidden hunger" for such essential micronutrients as iron, zinc and vitamin A afflicts more than half of humanity, especially women and children

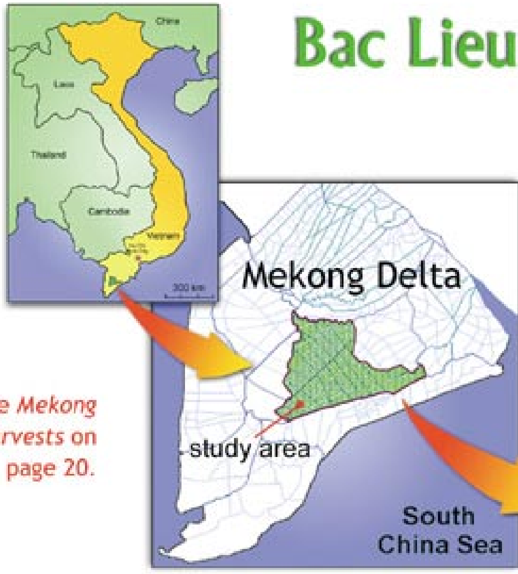
Diets lacking in iron and zinc cause problem pregnancies, stunted growth, delayed mental development and crippling fatigue. Vitamin A deficiency lowers defenses against disease for 250 million children and is the leading cause of childhood blindness

Biofortified rice will supply more of these micronutrients in the staple food of the poor

Better health through more nutritious rice

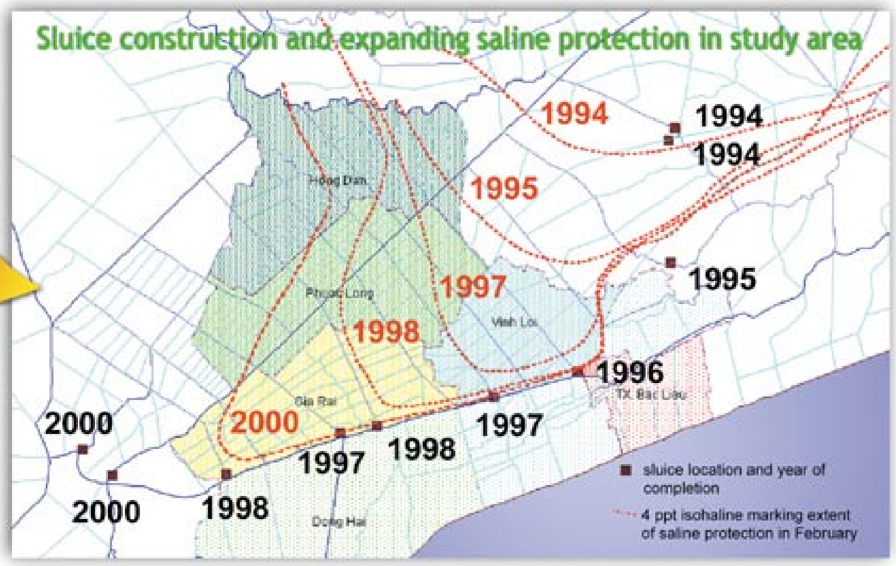
IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE
www.irri.org

Bac Lieu Livelihood Project



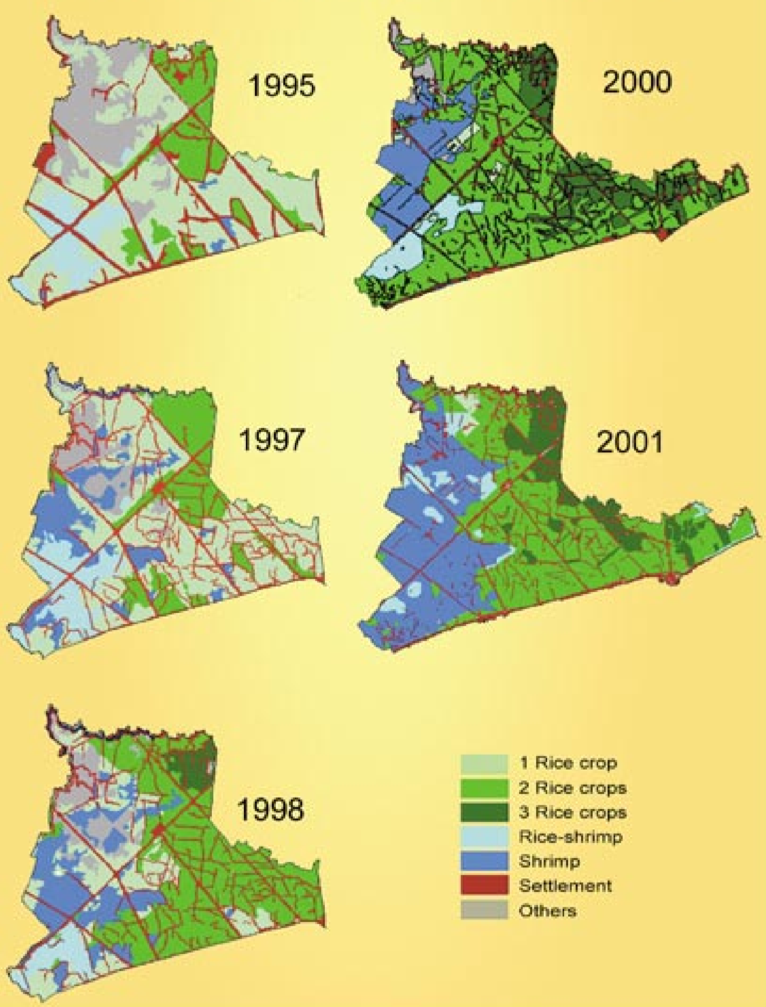
See *Mekong harvests* on page 20.

As construction of the Quan Lo–Phung Hiep Water Control Project progressed, a series of canal sluice gates blocked seawater inflow in the dry season, allowing farmers in Bac Lieu Province to grow two or three rice crops per year.

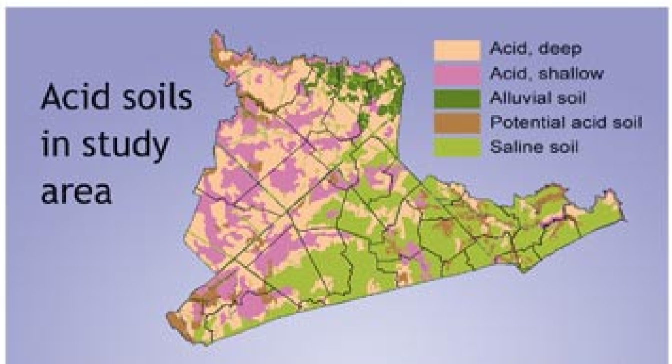


The western part of the study area, however, has acid soils unsuitable for intensive rice cultivation. Farmers in the west prefer to raise shrimp, and overall incomes declined as shrimp farmers lost access to the brackish water they needed to fill their ponds.

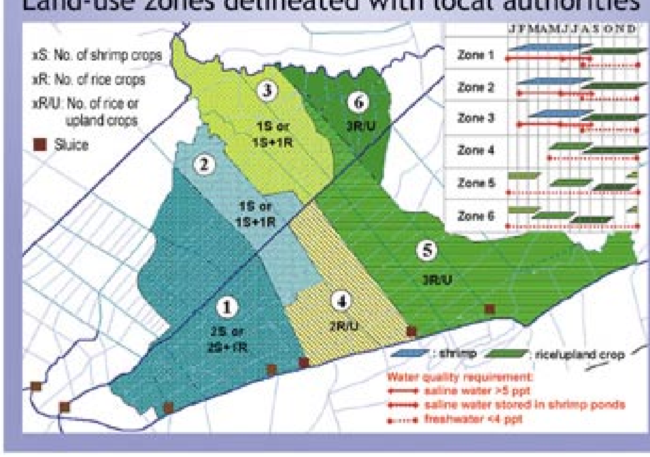
Expansion of rice in study area



To accommodate shrimp farming in the west, while preserving rice-production gains achieved in the east, researchers worked with local authorities to delineate land-use zones and develop a hydraulic model to determine sluice operation for controlling saltwater inflow in line with each zone's soil conditions and water-quality requirements. Successfully implemented in 2001, this resource-management strategy improves incomes for shrimp and rice farmers alike.



Land-use zones delineated with local authorities



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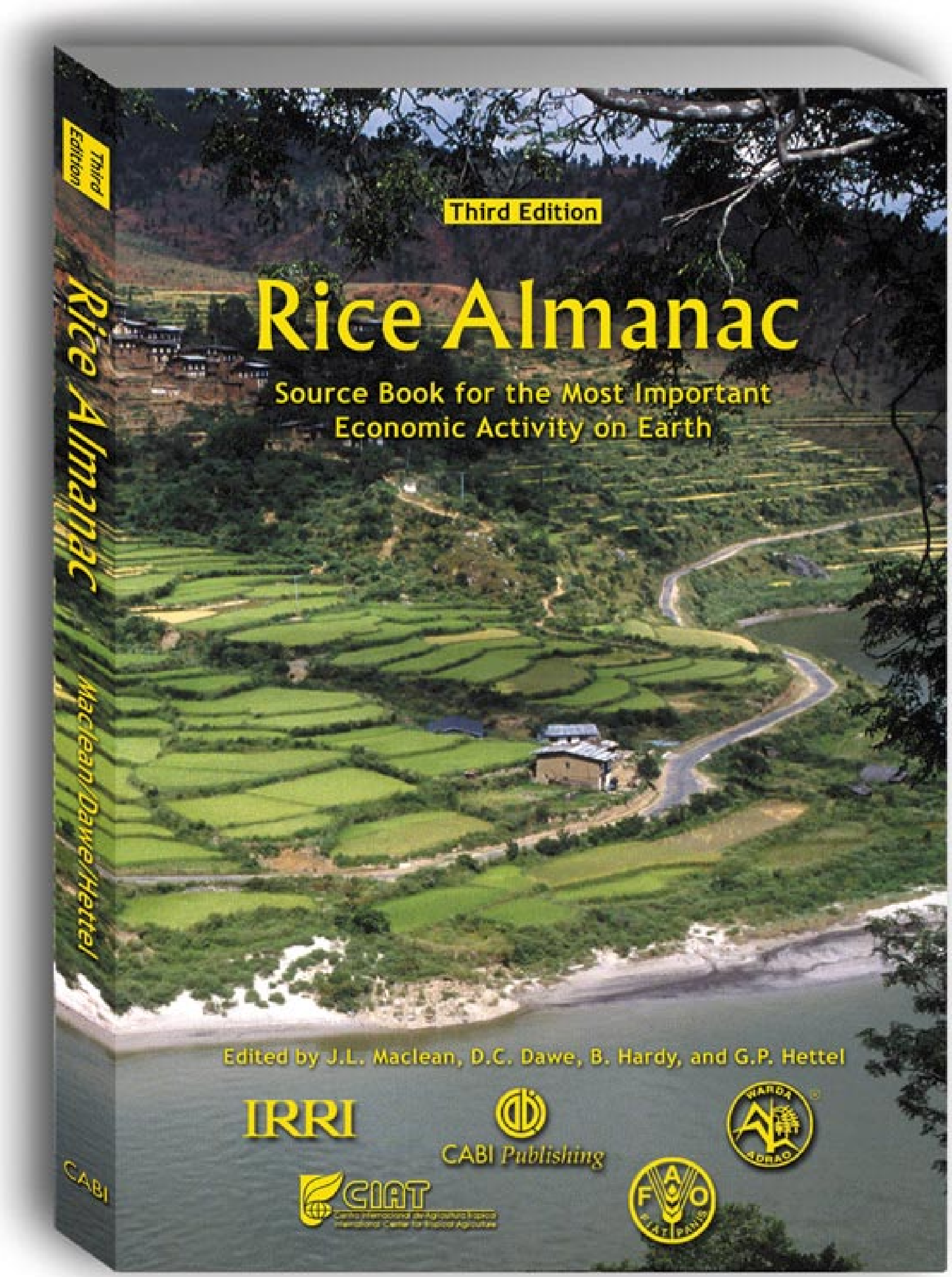

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