Rice Today

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International Rice Research Institute
October-December 2007, Vol. 6, No. 4

CHINA SPECIAL

Rice prices: what next?

Rice with less water

Vietnam and Laos
Making the uplands productive

Rice in China
Feeding the world's most populous country

ISSN 1655-5422

IRRC

Irrigated Rice Research Consortium

Improving farmer livelihoods in Asia: knowledge-intensive crop management for irrigated rice

The Irrigated Rice Research Consortium (IRRC), with support from the Swiss Agency for Development and Cooperation, promotes and sustains partnerships between national agricultural research and extension systems and the International Rice Research Institute to help farmers achieve increased profitability, food security, and environmental sustainability. The IRRC operates in Bangladesh, China, Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Sri Lanka, Vietnam, and the Philippines.

The IRRC focuses on innovative and adaptive research in the intensive lowland rice agroecosystems through four problem-solving work groups (Productivity and Sustainability, Water-Saving, Labor Productivity, and Postproduction). Mature technologies are disseminated through country outreach programs by

- Experimentally validating technologies in farmers' fields,
- Facilitating information exchange between research and extension agencies,
- Integrating principles and new technologies that lead to increased yields and more efficient crop production, and
- Developing effective pathways for scaling up technologies.

DOWNLOAD Ripple, THE QUARTERLY IRRC NEWSLETTER www.irri.org/irrc

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Raising productivity for rainfed rice ecosystems

Rainfed rice ecosystems are diverse and geographically dispersed across monsoon Asia. Farmers here face low, unstable yields and high rates of poverty. Research that delivers appropriate technologies must involve partnerships across international research centers, advanced research institutions in developing countries, national agricultural research and extension systems (NARES), and farmers' organizations.

The Consortium for Unfavorable Rice Environments (CURE), with support from the Asian Development Bank, provides a platform for research and technology validation at key geographically diverse sites in Bangladesh, Cambodia, India, Indonesia, Laos, Myanmar, Nepal, Philippines, Thailand, and Vietnam. The consortium is guided by a steering committee composed of research leaders of NARES and coordinated by the International Rice Research Institute (IRRI).

Through interdisciplinary research, CURE partners with men and women farmers to help them improve their living standards. CURE develops technologies that make a positive difference in rice productivity and rural livelihoods.

CURE · CONSORTIUM FOR UNFAVORABLE RICE ENVIRONMENTS

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Visit the CURE Web site at *www.irri.org/cure*

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On the cover: Xiaoguang Yang (*left*) and Huaqi Wang, researchers at China Agricultural University (CAU), examine aerobic rice—which yields well in unflooded fields—at the CAU experimental station on the outskirts of Beijing. Read more about aerobic rice in China on pages 28-33.

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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 13 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 15 centers funded through the Consultative Group on International Agricultural Research (CGIAR), an association of public and private donor agencies. For more information, visit the CGIAR Web site (www.cgiar.org).

Feeding billions—together

Last year marked the 30th anniversary of the first official contact between China and the International Rice Research Institute (IRRI). In 1976, the then director general, Nyle C. Brady, led a team of IRRI scientists to China for preliminary talks with their Chinese counterparts.

Formal planning for collaborative research and training programs with China began a few years later in 1982, with the Chinese Academy of Agricultural Sciences (CAAS) leading the talks. IRRI subsequently signed Memoranda of Understanding with a several Chinese agencies, including the Ministry of Agriculture, CAAS, Zhejiang Agricultural University, China Agricultural University (known then as Beijing Agricultural University), and the Center for Rural Development of the State Council. The same year, IRRI co-sponsored the first international agricultural research centers' book exhibition in China. The Institute also played a significant role in the establishment of the China National Rice Research Institute.

For Chinese agriculture, by far the biggest impact of IRRI's research was in hybrid rice. In the 1970s, rice production remained low across much of China and the famines of the 1960s were still well remembered. Hybrid rice was seen as a way to increase China's rice production and solve its food security problems once and for all. History shows the strategy was a major success, boosting Chinese rice production by 350 million tons from 1976 to 2000—but things had not looked so bright early on.

By 1969, Chinese scientists had identified two of the three parent rice lines required to breed hybrid varieties, but were missing the crucial third. It so happened that most of these so-called restorer lines were subsequently provided by IRRI. Nanyou 2 and Weiyou 6, the first Chinese hybrid rice varieties released, had IRRI varieties IR24 and IR26, respectively, as restorer parents. In the 1980s, more than 5 million hectares of land were planted annually with Shanyou 63, an indica hybrid rice with IR30 as its restorer donor.

It is now estimated that almost 90% of the hybrid rice in China—which provides more than 50% of the national harvest—originated from IRRI parent material and has an estimated value of more than US$12 billion. For more on the hybrid rice story, see *A hybrid history* on pages 22–25.

And that's not all. China-IRRI collaboration has led to several other important breakthroughs in rice research, including the development of aerobic rice technologies to help farmers battling water shortages (see *High and dry* on pages 28–33) and the use of biodiversity—or the interplanting of different rice varieties—to control rice diseases.

In 2000, the *New York Times* said of the interplanting research:

> *"In a stunning new result from what has become one of the largest agricultural experiments ever, thousands of rice farmers in China have doubled the yields of their most valuable crop and nearly eliminated its most devastating disease—without using chemical treatments or spending a single extra penny."*

With results like these, IRRI recognizes that its partnership with China is fundamental to the success and impact of its research agenda. At the same time, IRRI's contributions to rice research in China have clearly shown the importance of international collaboration, even for the world's biggest rice producer.

Duncan Macintosh
Publisher

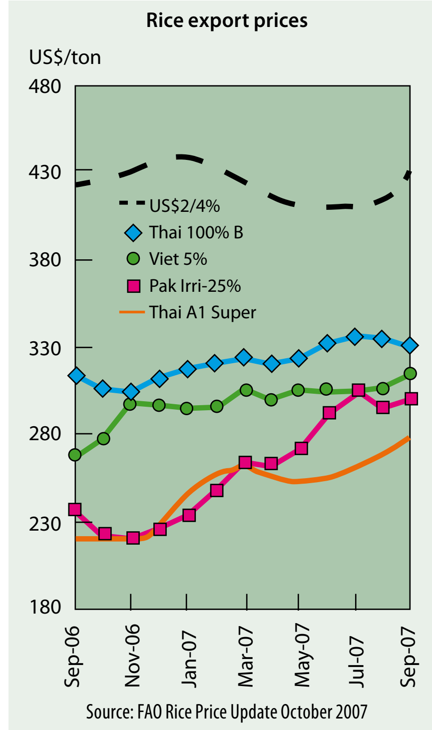
Rice prices still rising

International rice prices continue to rise, maintaining an upward trend since March, according to the Food and Agriculture Organization's *Rice Market Monitor*. Prices of aromatic rice, in particular, have continued to surge, due to low export availability. Record-low rice reserves, extreme weather events, fickle monsoon rains, pest and disease outbreaks, and a weakening U.S. dollar are some of the key factors that have combined to push up prices.

A recent page-one story in the 28 September edition of the *Wall Street Journal* said that, "Rising prices and surging demand for the crops that supply half of the world's calories are producing the biggest changes in global food markets in 30 years, altering the economic landscape for everyone from consumers and farmers to corporate giants and the world's poor." The story quoted Dan Basse, president of Chicago-based commodity forecasting company AgResource Co., as saying that, "The days of cheap grain are gone."

In addition, the 23 September edition of India's *Economic Times* newspaper noted that India's rice production is struggling to meet domestic demand. India was consistently exporting 5 million tons of rice every year, but, "Instead of keeping pace with demand, this *kharif* [the summer, or monsoon, season], production has been stagnant at 80 million tons, according to the first advance crop estimates ... With wheat harvests already whimsical, the last thing India needs is unpredictable rice production. We managed to tide over the wheat shortage only by pushing more rice into ration shops. If rice itself is scarce, India would be in the proverbial hot soup."

In the face of the rising prices, Vietnam has banned further exports until 2008. The September decision, by the agriculture ministry, is designed to ensure domestic food security. Vietnam's 2007 export target of 4 million tons has already been reached. There are also concerns that extreme weather and pest infestations may lower production, which, in September, was down 200,000 tons compared to the same period in 2006.



Source: FAO Rice Price Update October 2007

Asia-Pacific nations urged to study biofuels

The nations of Asia and the Pacific are being urged to study biofuels with greater care, before deciding on how they will use their agricultural industries to generate energy.

Scientists say there is an urgent need to support the current rush toward major decisions on biofuel policies in Asia and the Pacific with solid research and unbiased information about their potential benefits, impact, and risks.

The appeal was issued at the end of a recent Expert Consultation on Biofuels organized by the Asia Pacific Association of Agricultural Research Institutions (APAARI) together with the Philippine-based International Rice Research Institute (IRRI), the International Crops Research Institute for the Semi-Arid Tropics in India, the Washington-based International Food Policy Research Institute, and the International Maize and Wheat Improvement Center in Mexico. The consultation was held at IRRI's headquarters in the Philippines on 27-29 August.

In the Asian region, both China and India are gearing up for substantial investments in biofuels. Malaysia and Indonesia are investing heavily in oil palm plantations for biodiesel production. The Philippines has mandated the blending of gasoline with 5% biofuel.

However, at the same time, China has banned the use of maize—a vital crop for national food security—in the production of biofuels.

The consultation focused on several issues:

- To discuss how bioenergy production may have an impact on global and regional food security and the sustainability of key agricultural systems in Asia
- To summarize the current understanding of bioenergy options for key crops and cropping systems in Asia
- To identify key options and research priorities for designing and evaluating integrated food-bioenergy production systems for Asia
- To develop a framework for research on biofuels in key agricultural systems of Asia and agree on follow-up activities, including meetings with public and private sector partners.


AN EXPERIMENTAL BIOFUEL rice field in Japan's Southern Tohoku region.

ADAM BARCLAY

NATIONAL TAIWAN UNIVERSITY

JAPANESE ARTIST Mitsuake Tanabe helps unroll a smaller version of the giant drawing of a wild rice seed he has donated to National Taiwan University. Mr. Tanabe has been devoted to the restoration of wild rice in the international arena for many years. He creates giant works of art using wild rice as the theme to promote the idea of rice conservation. One example is the massive 7.5-ton Momi (Japanese for unhulled rice) that he produced especially for IRRI's Riceworld Museum, and which was unveiled there on 18 August 1994.

South Asian floods devastate rice lands

Severe floods, which killed more than 2,000 people and displaced millions, have devastated rice-growing areas in India, Bangladesh, and Nepal.

In low-lying Bangladesh, where 40% of the country was hit by floods, there were concerns that the disaster would stem the growth of the agriculture-dominated economy.

The heavy rains and flooding, which extended through June, July, and August, affected several million hectares of farmland, most of which was dominated by rice. In the worst-hit Indian state of Bihar, damage to crops and property covering 1.1 million hectares was estimated at around US$40 million dollars. Agricultural experts there said that rice would be unable to survive more than a few days of complete submergence.

One promising sign, however, was the performance of a new submergence-tolerant rice variety developed by IRRI (see *From genes to farmers' fields,* pages 28-31 of *Rice Today* Vol. 5, No. 4).

Trial crops of Swarna-*Sub1* were totally submerged for 10 days. But, when the floodwaters receded, the crop made a near-full recovery. According to the Bangladesh Rice Research Institute, the technology may offer protection to millions of farmers hit by floods each year.

Rice vaccine offers hope for fighting cholera

A team of Japanese researchers has developed a rice-based vaccine that offers mice protection against cholera. The team is optimistic that such a vaccine could also provide humans with resistance to the bacterium, which kills thousands of people each year, mostly in developing countries.

Tomonori Nochi, from the University of Tokyo's Institute of Medical Science, and colleagues inserted a gene from the bacterium, *Vibrio cholerae*, into the genome of a rice plant. The gene caused the rice to express a subunit of the cholera toxin that causes disease. A small amount of the subunit accumulated in the rice grains, which were powdered and fed to mice.

According to the researchers' report on 26 June 2007 in the *Proceedings of the National Academy of Sciences* (USA), the mice's immune system consequently produced antibodies that neutralized the cholera toxin.

There are several advantages to such orally administered protection, compared to the current injected vaccine. The rice vaccine can be stored at room temperature for at least 1.5 years, making storage cheaper and safer than that of conventional vaccine, which must be refrigerated. Second, there is no need for potentially dangerous syringes, which also make the treatment more expensive. Such a vaccine is thus ideal for mass vaccinations in developing countries.

Journalists' eyes opened to rice

Western journalists had their eyes opened to rice farming, Asian style, at the 51st Annual Congress of the International Federation of Agricultural Journalists in Japan on 17-23 September. It was the first time the Congress was held in Asia.

Many participants—who were predominantly from Europe and North America—had little prior exposure to Asian agriculture. The week involved seminars, debates, and visits to agricultural sites in the cities of Tokyo and Sendai, and the Southern Tohoku region. Rice dominated the visits and the ensuing discussions, as non-Asian participants began to appreciate the importance of rice to Japan in particular and Asia in general.

Rice-focused activities included visits to mills, organic rice farms, and biofuel research stations, and demonstrations of planting equipment.

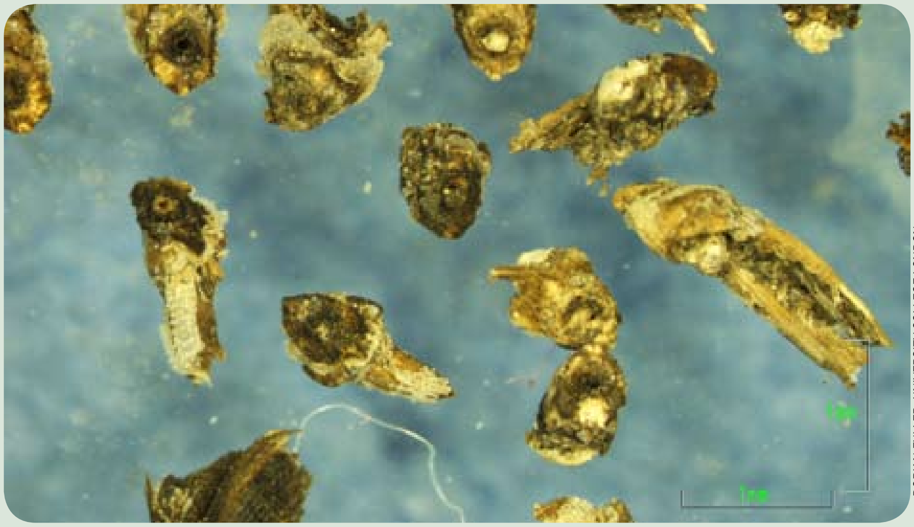
Early in the week, many journalists viewed rice in Asia as a mere agricultural commodity, to be produced and traded according to economic whims. In this light, some participants found it difficult to comprehend some of Japan's rice policies—such as 700–800% tariffs on imports and high domestic prices.

By the end of the Congress, however, most delegates had gained a sense of the enormous cultural, historical, and social importance of rice to Japan. When viewing the rice industry through this lens, previously arcane policies began to make sense. Although some journalists did not agree with all of Japan's decisions on rice, they at least gained an understanding of the thinking behind them.

JOURNALISTS VIEW a GPS-enabled rice planter, which does not require a driver.

ADAM BARCLAY

Ancient grains



DORIAN FULLER, UNIVERSITY COLLEGE LONDON

RICE OF AGES

The photograph at right shows small attachment points of 6,500–7,000-year-old rice spikelets (a spikelet is a unit of the rice flower). Dating from 5000 to 4500 BC, the spikelets were excavated in April 2006 at Tian Luo Shan in Zhejiang Province, China, by University College London archeologist Dorian Fuller and his collaborators from Zhejiang Provincial Institute of Archaeology, the Institute of Archaeology of the Chinese Academy of Social Science, and the School of Archaeology and Museology.

"The spikelets were left after the grain had been removed from rice for consumption," said Dr. Fuller. "They allow us to study the proportion of rice at that time that was adapted to human cultivation, compared with wild rice."

EARLY PADDY CULTIVATION

In China, UK and Chinese researchers have uncovered a snapshot of rice farming almost 8,000 years ago. The study by Yongqiang Zong et al, reported in the 27 September 2007 issue of *Nature*, analyzed the organic contents of soil sediments in Kuahuqiao, in the Lower Yangtze region of China, a center of rice domestication. Some 7,700 years before present, the Neolithic communities there chose lowland swamps for rice cultivation. These early farmers used fire to first clear wetland scrub and then to maintain paddy-style wet grassland vegetation. Flooding was probably controlled by bunds (short earthen walls). Around 150 years later, the site was abandoned because of inundation from rising seawater, a result of warming temperatures after the preceding glacial period.

The study provides evidence that rice cultivation began in coastal wetlands of eastern China.

RICE EVOLUTION

Meanwhile, a paper published in the August 2007 issue of the online journal *PLoS Genetics* indicated that the species that make up most of today's cultivated rice, *Oryza sativa*, evolved around 10,000 years ago from red-colored wild rice in the Himalayan Plains. The research team, led by former IRRI scientist Susan McCouch, now professor of plant breeding and genetics at Cornell University, found that nearly 98% of all today's white rice is a product of a single DNA mutation that is not seen in any wild red rice species. The mutation deletes part of a protein that helps determine grain color. The white varieties may have been favored because they cooked faster than nonwhite rice that was also consumed at that time.

BRIEFLY BRIEFLY BRIEFLY

Certification for IRRI farm

IRRI's Experiment Station (ES) Environmental Management System was ISO 14001 certified in August. According to ES manager Arnold Manza, ISO 14001 is an internationally recognized standard for environmentally sustainable systems, and as such demonstrates IRRI's commitment to environmental sustainability. The award required strict environmental policies to be planned, implemented, and monitored for compliance. One example of the environmental progress on the ES is the 95% reduction in pesticide use since the station was first created.

Indonesian award

Indonesia's 2007 Achmad Bakrie Award, presented for outstanding achievement by a person or institution, has gone to the Indonesian Center for Rice Research for its development of rice technology supporting food security.

China joins rice body

China has become a member of the International Rice Commission (IRC). Founded in 1949 by the The Food and Agriculture Organization of the United Nations, the IRC—currently with more than 60 member countries and regions—promotes cooperation among members in rice production, storage, distribution, and consumption. The Commission also discusses rice-related science and technology and economic issues, and encourages and coordinates research cooperation.

Africa rice shortage?

Diminishing imports from Asia are threatening a rice shortage in Kenya—and possibly all of Africa—according to agricultural experts there. However, Africa Rice Center Director General Papa Abdoulaye Seck said that a crisis could be averted if African governments focus on boosting regional production and avoid dependence on imports. Dr. Seck predicted the trend would continue due to rising demand in the growing populations of Asia coupled with a reduction in land under rice.

Thailand, IRRI sign rice pact

Thailand's Ministry of Agriculture and Cooperatives and IRRI have signed an agreement to expand their existing bilateral cooperation in rice development to increase the value of Thai rice, according to Thai Agriculture and Cooperatives Minister Thira Sutabutr. The agreement was signed by Mr. Thira and IRRI Director General Robert Zeigler in Thailand on 27 June. Under the terms of the agreement, cooperation between Thailand and IRRI would be upgraded from the department level to the ministry level.

Chair Change

QUEENSLAND DPI

The International Rice Research Institute (IRRI) has announced the appointment of leading Australian agricultural scientist **Elizabeth Woods** (pictured, *left*) as the new chair of its Board of Trustees. A former Rhodes Scholar and winner of several honors in Australian agriculture, Dr. Woods is recognized as an expert in tropical and subtropical agriculture and agribusiness.

She takes over from **Keijiro Otsuka**, a respected agricultural economist from Japan, who is stepping down officially after almost 4 years in the position. IRRI's independent 15-member Board of Trustees meets twice a year to set the Institute's policies and review its research agenda.

RETIRING IRRI BOARD member Eun-Jeong Lee with local children after the board meeting in Laos.

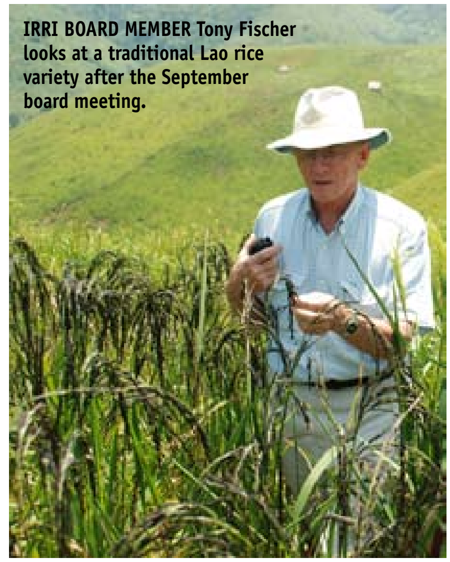
BEN SAMSON (2)

The Board met on 19-21 September 2007 in Vientiane, Laos, to confirm the new appointment, which is effective 1 January 2008.

Dr. Woods is currently Foundation Professor of Agribusiness at the School of Natural and Rural Systems Management at the University of Queensland in Australia. She previously chaired Australia's Rural Industries Research and Development Corporation.

Dr. Woods, who was elected to the IRRI board two years ago, takes over as chair at a time of unprecedented challenge and opportunity in rice research and production. "World food reserves, including those for rice, are low and cereal prices are high. In this context, my priorities will be to focus IRRI on its core mission—to improve the efficiency and sustainability of rice production," Dr. Woods said.

"IRRI needs to continue to further strengthen its work with all its partners in the national agricultural systems around the world, as well as with other international research centers, to maintain its impact, especially in such important areas as adapting rice production to climate change."



IRRI BOARD MEMBER Tony Fischer looks at a traditional Lao rice variety after the September board meeting.

Dr. Woods said she would particularly encourage IRRI to focus on the needs of rice farmers and others in the rice supply chain, including the many women who are playing increasingly important roles in their family farms and professions.

Dr. Otsuka said that one of his most important achievements as board chair was helping to reorient IRRI's mission to focus more sharply on poverty reduction in poor rainfed areas in Asia, but also including sub-Saharan Africa. "This new focus is backed by a very strong commitment to rice research and the use of science to solve problems—something that has always been key to IRRI's success," he said.

Also leaving the board after 6 years' service are **Eun-Jong Lee** from Korea and **Achmad M. Fagi** from Indonesia.

Keeping up with IRRI staff

Former IRRI consultant scientist **Marco Wopereis** has been appointed as The Africa Rice Center's (WARDA) incoming assistant director general, research and development. He will take up his new functions in December 2007.

Former IRRI staff member **Richard Lando** passed away on 27 June. In 1989-91, Dr. Lando was based in IRRI's Cambodia office as a technology transfer specialist, where he worked to improve agricultural production in Cambodia and helped establish a national agricultural extension program.

Crop and Environmental Sciences Division (CESD) Head **T.P. Tuong** is serving as acting deputy director general for research until former deputy director Ren Wang's replacement arrives. **Bas Bouman** has taken over as acting head of CESD during the same period. **Dirk De Waele**, a professor at K.U. Leuven, Belgium, has joined CESD part time to lead nematology research at IRRI. He will visit IRRI three times a year for 2–3-week periods.

At the Cuu Long Delta Rice Research Institute's (CLRRI) 30th anniversary celebrations in Ho Chi Minh City, six IRRI staff members were awarded with medals in recognition of their contributions to rice research in Vietnam. The awardees were Director **Robert Zeigler**, **Grant Singleton**, **Abdelbagi Ismail**, **Darshan Brar**, **Il-ryong Choi**, and **T.P. Tuong**.

J.K. Ladha, IRRI representative in India, started his study leave at Cornell University on 1 July. **Kyu-Seong Lee** joined IRRI's Plant Breeding, Genetics, and Biotechnology Division as senior scientist, seconded from Korea's Rural Development Administration. His major responsibilities are to develop temperate japonica rice varieties that can be adapted to the tropics, generate breeding materials, and multiply seeds of elite breeding lines.

Achievements and appointments

AILEEN RONDILLA

Entomologist **Gary C. Jahn** (pictured, *right*), IRRI coordinator for the Greater Mekong Subregion, will receive an International Plant Protection Award of Distinction from the International Association for the Plant Protection Sciences. Dr. Jahn, who was scheduled to receive the award on 15 October at the International Plant Protection Congress in Glasgow, Scotland, was honored for major contributions to the promotion of global plant protection.

IRRI Board of Trustees member **Ralph Anthony ("Tony") Fischer** (pictured, *left*) was included in the 2007 Queen's Birthday Honors List announcements when he was named as a member of the Order of Australia (AM). He is recognized for his "service to agricultural science in Australia and developing countries, particularly wheat research in the areas of grain yield and crop cultivation and management." Dr. Fischer was also awarded the 2007 Farrer Memorial Medal, which honors distinguished service in Australian agricultural science. He received the award on 14 August at a ceremony in Australia's capital, Canberra, at which he gave the 2007 Farrer Oration, *Improvement in Wheat Yield: Farrer, Physiology, and Functional Genomics,* which discussed the past successes of Australian wheat breeding and the challenges of the future.

Former IRRI Deputy Director General for Research **Ren Wang** was awarded an honorary professorship by China's Huazhong Agricultural University. Dr. Wang, now director of the Consultative Group on International Agricultural Research, was recognized for his contributions to agricultural research and capacity building of national agricultural research and extension systems.

Nobel Peace Prize Laureate **Norman E. Borlaug** received the highest honor that the U.S. Congress can bestow upon a civilian—the Congressional Gold Medal. Dr. Borlaug was honored for his work that spurred the Green Revolution of the 1960s, for which he is credited with saving more than one billion lives. The Medal was presented on 17 July in the U.S. Capitol Rotunda by President George W. Bush and Speaker of the House Nancy Pelosi.

CLAESSENS PERSONAL COLLECTION

THE RICE OF ROME: *Rice Today* reader Geert "Jef" Claessens, from Belgium, shows off his *Rice Today* T-shirt in front of the Colosseum in Rome. Any readers who send in a photograph of themselves holding a copy of the magazine in front of a famous landmark will receive a free T-shirt.

David Mackill, program leader for rainfed environments, has been elected as a Fellow of the American Society of Agronomy (ASA) for 2007. He is scheduled to receive his award during the ASA annual meeting on 4-8 November in New Orleans, USA. IRRI consultant **Gelia Castillo** was named this year's Most Distinguished University of the Philippines (UP) Alumna during the UP General Alumni-Faculty Homecoming and Reunion at UP's Diliman campus in Manila on 23 June.

Zakaria L. Kanyeka has joined IRRI as regional plant breeder for East and Southern Africa (ESA), based in Dar es Salaam, Tanzania. He will work with IRRI staff and the national rice programs to develop a regional rice breeding plan and rice seed multiplication guidelines for ESA countries. **Achim Dobermann** has returned to IRRI as leader, Program 2 (*Sustaining productivity in intensive rice-based systems: rice and the environment*), as well as project leader for the IRRI–International Maize and Wheat Improvement Center (CIMMYT) Alliance Project on Intensive Production Systems in Asia. **Norman Macdonald** has joined the Institute as director for management services. He will serve as IRRI's chief financial officer.

Looking up in

Story by Adam Barclay, photos by Ariel Javellana

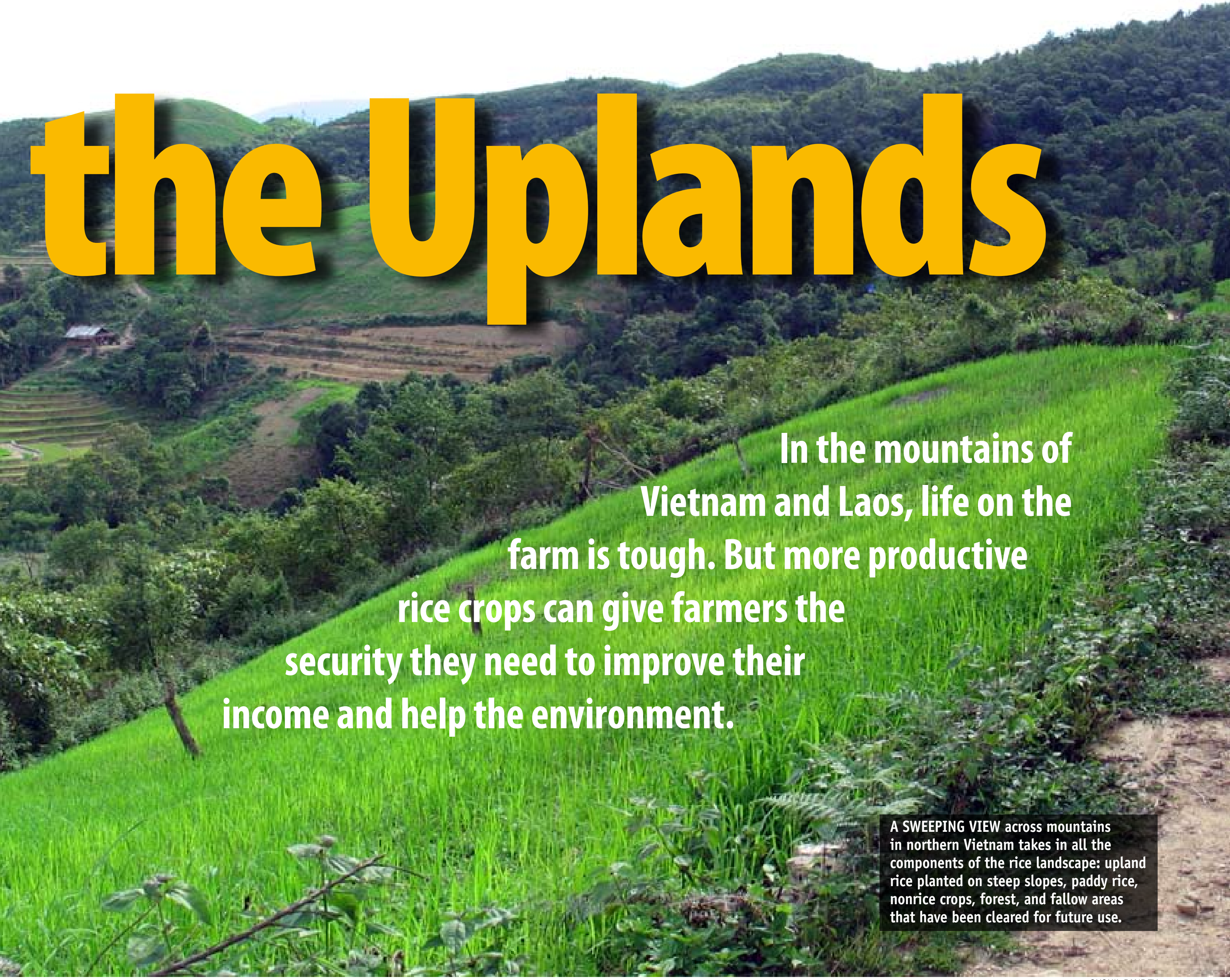
The land around Pang Cang village of Suoi Giang Commune in Vietnam's northern province of Yen Bai is steep. To give you an idea of just how steep, when the locals cycle down to Van Chan, 12 kilometers away, some of them hook a tree branch to the back of their bike to act as an extra brake. Some don't even bother keeping a chain on their bikes—you either roll downhill or walk up. Riding uphill is not an option.

Seeing this terrain for the first time, one can't help but ask: why on earth would anybody want to farm this land? On hills that most people would refuse to hike, people plant rice, maize, tea, cassava, soybeans, peanuts, and more. There is no irrigation for these sloping uplands; farmers rely solely on the wet-season rains that (they hope) begin in May or June. And these slopes are not farmed for their high yields. In some cases, 100 kilograms of seed produces a mere 800 kilograms of rice at harvest. The answer, then, is that nobody would *want* to farm here—they do it because they have no choice.

Not far away, in the agriculturally and climatically similar uplands of northern Laos, the situation is the same. Through a lack of alternatives, families are forced to farm land that sucks in everything that's thrown at it—from seeds to arduous, spirit-crushing labor—and offers little in return.

"Who would do that if they had other options?" asks Sushil Pandey, senior agricultural economist at the International Rice Research Institute (IRRI). Dr Pandey, leader of IRRI's *Rice policy support and impact assessment* research program, is leading two projects in Vietnam and Laos, as well as India and Nepal (see *Who, what, and where* on page 15). The research team is investigating ways of improving food security, reducing poverty, and minimizing environmental degradation in the uplands. His question is rhetorical. The point is that most people here

the Uplands



In the mountains of Vietnam and Laos, life on the farm is tough. But more productive rice crops can give farmers the security they need to improve their income and help the environment.

A SWEEPING VIEW across mountains in northern Vietnam takes in all the components of the rice landscape: upland rice planted on steep slopes, paddy rice, nonrice crops, forest, and fallow areas that have been cleared for future use.

SUSHIL PANDEY

don't have alternatives. The only land they can use is on these steep slopes. With very little income, they have no choice but to eke out a living by growing their food here.

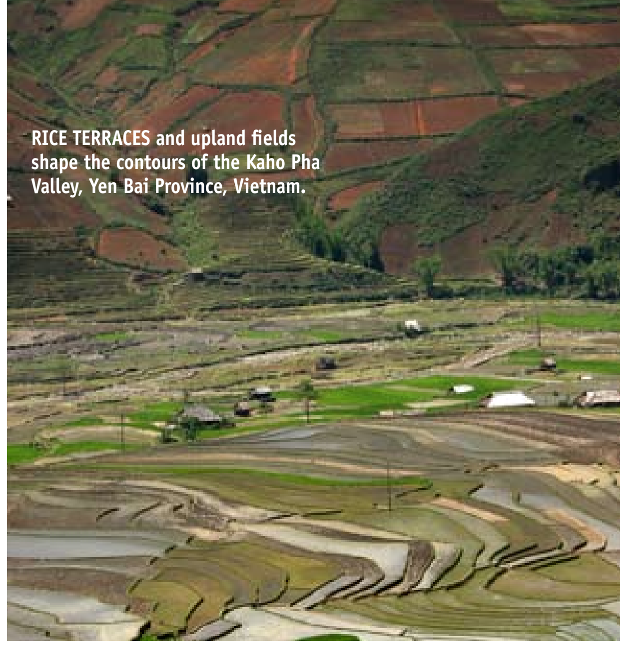
"What we want to do," says Dr. Pandey, "is to help them develop options."

And the key that can unlock alternatives for the farmers is rice—specifically, increased rice productivity. Dr. Pandey sees producing more rice on less land, and with less labor, as one of the most promising entry points for breaking out of what IRRI calls the vicious circle and moving into the virtuous circle (see figures on page 12).

There are several key constraints to agricultural production and income for farmers on sloping uplands. Most visibly obvious is the unforgiving fragmented topography, which forces people to work on gradients of more than 25 degrees up to a backbreaking 45 degrees. The predominant mode of agriculture on these slopes is shifting cultivation—otherwise known as slash-and-burn farming. This involves farmers clearing and burning a patch of land on which they grow crops for a few seasons before leaving the land fallow and moving on to another patch of land. After a time, they return to the original area, cycling through as many plots of land as are available, and giving the mountainsides in northern

HA DINH TUAN (*front*) and Sushil Pandey lead the research team along a mountain trail in northern Vietnam.

A RICE FARMER prepares paddies near Sai Luong village, Nam Bung Commune, Vietnam.



RICE TERRACES and upland fields shape the contours of the Kaho Pha Valley, Yen Bai Province, Vietnam.

Laos and Vietnam their distinctive green-brown-black patchwork look.

The endemic poverty in these areas means that farmers either can't afford or are unwilling to buy basic inputs such as fertilizer. Living conditions are as austere as they come. Many people live in small huts with a few basic possessions—little more than some cooking pots and a few utensils. This tenuous day-to-day existence means that farmers in these unfavorable areas are risk-averse and either unable or reluctant to invest in technologies that may help them later.

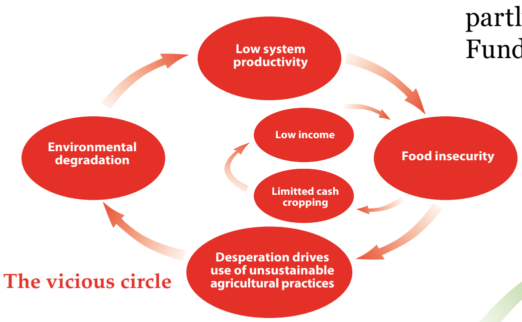
The harsh weather—long, dry, cold winters and very wet, hot summers—is another major constraint. Pests and weeds are constant problems and weed management requires intensive labor (manually weeding flat fields is a thankless task in itself; imagine doing it in the scorching, humid summer on muddy, 45-degree slopes).

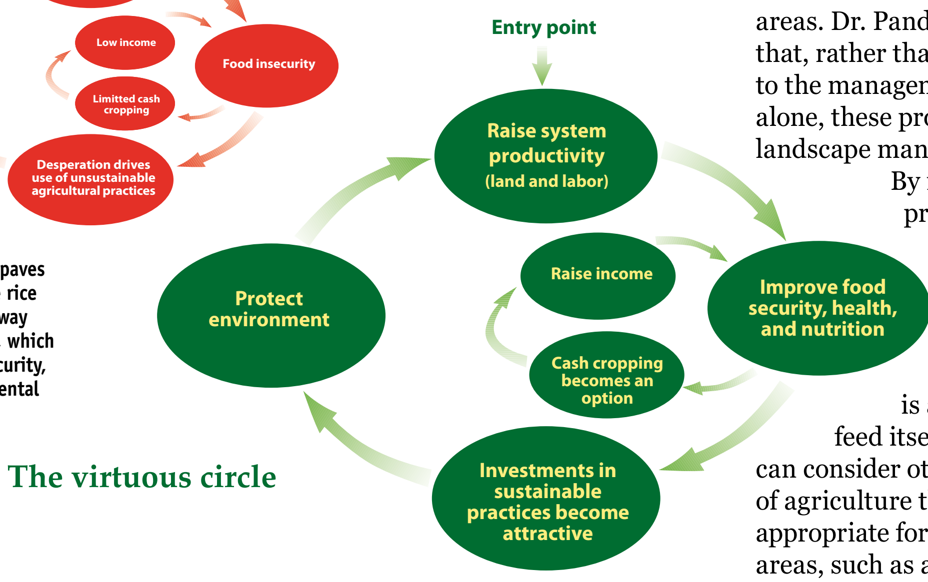
Compounding the problem of poor productivity is inadequate access to markets. Even if farmers do manage to grow a cash crop or a rice surplus, many farms are several hours along narrow mountain footpaths from the nearest place where they can sell their produce.

The research, which represents IRRI's strategic efforts to reduce poverty and improve environmental sustainability in uplands, focuses on managing rice landscapes in marginal uplands. The projects—partly funded by the International Fund for Agricultural Development (IFAD) and the Consultative Group on International Agricultural Research (CGIAR) Challenge Program on Water and Food (CPWF)—aim to develop, validate, and deliver technologies for poverty reduction through improved management of rice landscapes while also improving the way water is used in poor farming areas.

The "rice landscapes" approach calls for intensification of food production in favorable pockets of the uplands so that pressure to intensify production in the less favorable, more fragile areas can be reduced. These favorable pockets include productive wetland paddies in valley bottoms and terraced fields (or "upland paddies") where irrigated rice can be grown. They also include dry terraces and fields with lower slopes that are better able to retain moisture and nutrients than the steeply sloping areas. Dr. Pandey emphasizes that, rather than being limited to the management of rice fields alone, these projects are about rice landscape management as a whole.

By increasing rice productivity, farmers can free up land and labor for cash crops or other income-generating activities. If a family is assured enough rice to feed itself each year, farmers can consider other components of agriculture that may be more appropriate for these steeply sloping areas, such as animal husbandry, tree





THE VIRTUOUS CIRCLE paves the way to sustainable rice production and does away with the vicious circle, which perpetuates food insecurity, poverty, and environmental degradation.

Moving down to move up

Chanh Tuln (*pictured*) is a farmer who lives in Muka village, Oudomxay Province, in northern Laos. The 57-year-old has four children: three sons, 26, 24, and 22, and a daughter, 13. His farm comprises 0.5 hectare of lowland (irrigated) area and 1 hectare of upland (rainfed) area. But that will soon change.

In 2006, Mr. Tuln was forced by a lack of labor to cultivate rice on only 0.3 hectare of his lowland farm. From this, he harvested 900 kilograms. Because of poor rainfall, his upland farm offered him a mere ton of rice. Despite these low yields, he and his family coped. A recently constructed road has linked Muka to other villages and, therefore, to markets where Mr. Tuln was able to sell his nonrice crops.

But 2006 also marked the beginning of Mr. Tuln's move away from upland farming. He received from the Oudomxay Provincial Agriculture and Forestry Office 5 kilograms of B6144, an improved upland variety that farmers have found grows well under lowland conditions also. This nonglutinous variety yields higher than the traditional glutinous (sticky) varieties favored by most people in this region.

The seeds were part of 1,500 kilograms of modern and purified traditional varieties supplied as part of the *Managing landscapes in marginal uplands for household food security and environmental sustainability* project to 150 farmers in 22 villages for an initial demonstration. Mr. Tuln planted half of his seeds in his lowland fields and gave half to his brother. Each of them harvested 100 kilograms.

"We're very happy with B6144 because it's high-yielding," says Mr. Tuln. I saved 30 kilograms of seed and this year will sow 10 kilograms. I'll give 20 kilograms to relatives and keep 70 for eating."

Because of B6144's increased yield, Mr. Tuln planned to plant only this variety in lowland fields in 2007. This will allow him to use his upland plots to plant more cassava and maize, which require less weeding (and therefore less labor) than rice, and which he can sell. Consequently, Mr. Tuln is anticipating a higher income in 2007, which will allow him to buy medicine and clothes for his family and help pay for his daughter's schooling.

The news of success stories like Mr. Tuln's has traveled rapidly through Oudomxay Province. More and more farmers are keen to obtain seeds of improved varieties and try them for themselves.

But most farmers in upland areas have very small areas of lowland fields or none at all. Restricted to growing rice in sloping upland areas, they need rice varieties that can produce higher yields. Several upland farmers involved in the project are already seeing increased yields through their use of purified stocks of popular traditional varieties such as Nok, Makhinsong, and Chaomad (see *Appropriate technologies* on page 14).

Only when poor farmers achieve a secure food supply can they can begin to think about how to increase and diversify their income by, for example, growing cash crops or raising livestock.

plantations, or forestry production.

There are other flow-on effects that stem from increased rice productivity. Ultimately, it will mean that the amount of land used for shifting cultivation, which encroaches on forests and contributes to environmental degradation, will decrease.

"The basic motto of our work is 'income growth with household food security,'" says Dr. Pandey. "Often these are seen as competing goals. What we are saying is that you can have income growth built on the foundation of food security. If you can use fewer resources to grow food, you free up resources so that you can start the process of income growth."

There have been attempts in the past to encourage upland farmers to reduce the amount of land they plant to rice and grow crops that can be sold on the external market, thus raising income and allowing people to buy the extra rice they need to feed themselves. IRRI social scientist

Appropriate technologies

RANDY RITZEMA monitors water activity at a research site in Luang Prabang, Laos.

Offering farmers appropriate technologies can help them shift from the vicious to the virtuous circle. Such technologies include

- *New and improved seeds.* These are improved aerobic varieties suited to upland conditions that produce higher yields than the varieties currently being grown (suitable aerobic varieties can achieve 1–1.5 tons per hectare more than the 1–1.2 tons per hectare yield of traditional varieties).
- *New breeding lines.* Through the International Network for Genetic Evaluation of Rice, Lao and Vietnamese national research institutes have received breeding lines that are being used to identify improved rice varieties adapted to both paddy (irrigated) and upland (nonirrigated) conditions.
- *Purification of seed stocks of traditional rice varieties.* Most farmers in the sloping uplands plant from a mixed seed stock. Identifying the best traditional varieties for the prevailing conditions and management practices, and using pure stocks of these, result in better yields. Local agricultural agencies will have the responsibility of training farmers to maintain pure seed stocks. In Laos, where NAFReC has done most of the seed purification and multiplication work, there is interest in setting up a community-based seed production system to meet local seed requirements.
- *Best-practice management of rice cropping systems.* For example, the addition of short-duration legume crops such as soybean or mungbean, or direct seeding of rice in rainfed lowlands, may allow farmers to harvest earlier and grow a second rice crop in one year.
- *Alternative cropping systems.* These are crop combinations with upland rice and improved fallow rotations that reduce soil erosion and weed infestation, enhance soil fertility, and generate income. These systems include rice-based rotations with leguminous cash crops such as pigeon pea and paper mulberry, and rice-beans. Besides grain production, pigeon pea may also serve as a host for the insects that secrete *sticlac*, which is used as an industrial resin and fetches a good market price. After several years of harvesting *sticlac*, pigeon pea can be incorporated into the soil as a green manure in preparation for a return to rice or other crops.
- *Restoration of weed-infested areas.* For example, this involves combining appropriate herbicide use to control the perennial grass *Imperata*, which commonly invades land under short fallow rotations, and subsequently establishing pigeon pea to prevent reinfestation.
- *Technologies for soil fertility maintenance.* In combination with fertilizers, rice crops can be interspersed with crops that add nitrogen to the soil and/or deep-rooted species that enhance nutrient cycling.
- *Technologies for improved water use.* “Aerobic” rice varieties, which require less water than irrigated varieties, are an example of an important technology for increasing water productivity. Rice irrigation regimes, such as alternative wetting-and-drying similarly can increase water productivity by enabling farmers to plant a larger area of irrigated rice than would be possible otherwise.

RICE TERRACES near Pang Cang village, Suoi Giang Commune, Vietnam, allow a second yearly rice crop.

A SLASHED-AND-BURNED mountain top in Oudomxay Province, Laos. Farming on such steep slopes is backbreaking work.

Hari Gurung cautions that these strategies are often perilous, though.

“One option might be to encourage upland farmers to stop growing rice and grow cash crops such as tea, coffee, or rubber—but that can be socioeconomically disastrous,” says Dr. Gurung. “The subsistence-oriented highland communities are already vulnerable; rapid exposure to markets and fluctuating market forces can increase their vulnerability. If the market collapses, not only will people be left with nothing to eat, but they will also lose the basis of their livelihoods.”

Strategies to improve rice production in the sloping uplands (see *Appropriate technologies*, left) include the introduction of superior seeds (either higher-yielding modern varieties or pure seed stocks of high-quality traditional varieties) and improved management options that maintain or rejuvenate soil fertility. This approach includes better fallow systems in which legumes, for example, are planted and later incorporated into the soil.

Although the projects are still in their early stages, people in some

Who, what, and where

Two projects on rice landscape management are currently being managed by IRRI as part of a broader initiative in the uplands of Asia. The projects involve a wide range of international and national organizations:

- Assam Agricultural University, Assam, India
- Chiang Mai University, Thailand
- Nepal Agricultural Research Council, Nepal
- Institute of Agriculture and Animal Sciences, Nepal
- Indian Council of Agricultural Research Center for North-Eastern Hills Region, Meghalaya
- National Agriculture and Forestry Research Institute, Laos
- Northern Agriculture and Forestry Research Center, Laos
- Northern Mountainous Agriculture and Forestry Science Institute, Vietnam
- Thai Nguyen University of Economics and Business Administration, Vietnam
- World Agroforestry Center (ICRAF)
- French Agricultural Research Centre for International Development (CIRAD)
- University of California, Davis
- Yunnan Academy of Agricultural Sciences, Yunnan, China

The research program is funded through grants from the International Fund for Agricultural Development and the Challenge Program for Water and Food.

areas are already adopting improved technologies. In the Lao province of Oudomxay, for example, farmers are increasingly growing several varieties being promoted by the project. Some of these are improved varieties while others are local varieties adapted to upland conditions.

In 2006, the projects supplied 1,500 kg of seeds of improved and adapted traditional varieties to 150 farmers in several villages in northern Laos for an initial demonstration. The farmers are now expanding the area on which they grow these varieties. Neighboring farmers are also interested and have obtained seeds from the 2006 harvest. Thus, the dissemination of these varieties at the village level has already commenced.

Alternative cropping systems are being explored to identify crop combinations and rotations with upland rice that reduce soil erosion and weed infestation, improve soil fertility, and generate income. These alternative systems, which include rotations such as rice-pigeon pea, rice-ricebeans, and rice-paper mulberry, are also being validated and made available to farmers. In other areas, farmers have started to grow spring rice (a second annual rice crop planted in February and harvested in June) or plant spring legumes such as soybean, peanut, or pigeon pea.

FARMER LY HIEU Vuong, from Sai Luong village, Vietnam, was able to increase rice production considerably after adopting a higher-yielding variety.

DAMIEN JOURDAIN (*left*) stresses the importance of working with farmers. Ben Samson discusses upland farming options with the villagers of Muka, in the Lao province of Oudomxay.

According to Damien Jourdain, a Hanoi-based agricultural economist seconded to IRRI from the French Agricultural Research Centre for International Development (CIRAD), the project is implemented in partnership with farmers who are involved in the conduct and evaluation of various field trials—many of which are managed by the farmers themselves. Farmers are regularly invited to research trials to offer feedback on what they see as the technologies with the greatest potential. Thus, the projects avoid wasting time and money on technologies that may be well intentioned and scientifically sound, but would stand little chance of adoption. Examples include improved varieties that offer pest resistance and high yields, but have poor cooking quality, or nonrice winter crops that improve soil fertility but are prohibitively labor intensive.

Dr. Jourdain, whose project role includes supervision of several Vietnamese postgraduate students, points out that the work is valuable not only because it directly assists farmers but also because it helps build the capacity of the local research institutions. "I wouldn't underestimate the impact of working together with research partners and students," he says. "It's not just the whole impact of the project, but also the process of tackling a research question together. You can bring in some new ideas, some new methods."

According to Khamdok Songyikhangsuthor, agricultural scientist at Laos's Northern Agriculture and Forestry Research Center (NAFReC), as shifting cultivation fallow periods grow shorter—a trend accelerated by government policies of limiting the area under slash-and-burn-farming—there is a growing need for varieties suited to the shorter fallow cycles. Already, NAFReC's work to purify stocks of traditional seeds has resulted in higher yields for farmers.

SLASH-AND-BURN farming encroaches on forests and contributes to environmental degradation.

NAFReC Director Houmchithsavath Sodarak, who has been a champion for the project in Laos, notes that the Center is also evaluating several improved upland varieties generously provided by the Yunnan Academy of Agricultural Sciences.

"This has allowed farmers to start or increase the planting of cash crops—fruit trees, maize, soybean, for example—which can get good prices at the market," says Mr. Khamdok, who adds that, through the Lao provincial agriculture and forestry offices, NAFReC is also distributing improved nonglutinous (nonsticky) varieties. "Although most Lao ethnic groups prefer the glutinous rice," he says, "many farmers are starting to grow the nonglutinous rice because of its higher yields."

Farming in irrigated paddies—either flat areas in valleys or terraced slopes—is considered lowland farming, even if it's high in the mountains. These irrigated paddies, although limited in area, can produce much higher yields because of favorable conditions for rice growth. Often, farmers are unable to fully use such land for rice production due to a shortage of water, especially in the dry season. One of the project aims is therefore to develop and test water-efficient rice technologies, such as aerobic rice (rice that yields well when grown in flat but nonflooded fields) and alternate wetting-and-drying irrigation regimes. Such approaches have potential to ensure against unpredictable rainfall or allow farmers to grow a second rice crop each year.

"Irrigation in the mountainous areas is also very poor," says Ha Dinh Tuan, deputy director general of Vietnam's Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI). "We are wasting water. If we can preserve water better, we could avoid water shortages during the dry season. This requires a very big investment and the current irrigation systems are inadequate and may be uneconomical in some localities."

Environmental systems analyst Randy Ritzema, a University of California, Davis, Ph.D. student, is based in Luang Prabang, where he is investigating how water flows in upland farming areas. Using computer modeling and geographic information systems (mapping), he is looking at how land use in these areas has changed over time and how this is likely to affect water flows downstream.

"Rice production must be seen in the context of general environmental resource management—and the central resource is water," says Mr. Ritzema. "Once we understand where the water goes and how it's managed, and how that's related to land use, we can see if changing different components will help increase rice production and support income growth."

KHAMDOK SONGYIKHANGSUTHOR is an agricultural scientist at Laos' Northern Agriculture and Forestry Research Center.

The problem is, most farmers in these mountainous areas do not have access to flat land where paddy rice can be grown.

"Even though our objective is to give people options that will draw them away from the sloping uplands," says Ben Samson, an agronomist based in IRRI's office in the northern Lao city of Luang Prabang, "we are still doing work in these unfavorable areas because there is limited flat land available."

Both projects are now in their second year and the major thrust so far has been assessment and understanding of the relationships among rice production, landscape management, poverty, and water access and use. Dr. Samson says that once this phase is completed, researchers and farmers will develop and test technologies that can provide the transition from the vicious to the virtuous circle.

"We are already testing technological interventions, even as we undertake the assessment and understanding phase of the upland work," he says. "We are able to do this by using and building on previous collaboration between IRRI and the Lao National Agriculture and Forestry Research Institute."

The research team is optimistic about the projects' impact. "If we are able to put appropriate technologies in place, it shouldn't be too long before we see significant gains," says Dr. Pandey. A similar approach promoted by the Chinese government in China's Yunnan Province saw major improvements to farm families' livelihoods in 5–7 years (see *A mountainous success* on pages 30-35 of *Rice Today* Vol. 5, No. 1).

Having enough food is one of humanity's most fundamental requirements. Food insecurity acts as a wall between an arduous hand-to-mouth existence and a more fulfilling life. By providing options that help people feed themselves and their families, Dr. Pandey and his team hope to give upland farmers the boost they need to get over that wall.


ARIEL JAVELLANA

Where science meets art

As he prepares for retirement after 15 years at the International Rice Research Institute, molecular biologist John Bennett reveals himself as a scientist who not only appreciates art—he blurs the distinction between art and science

by Meg Mondoñedo

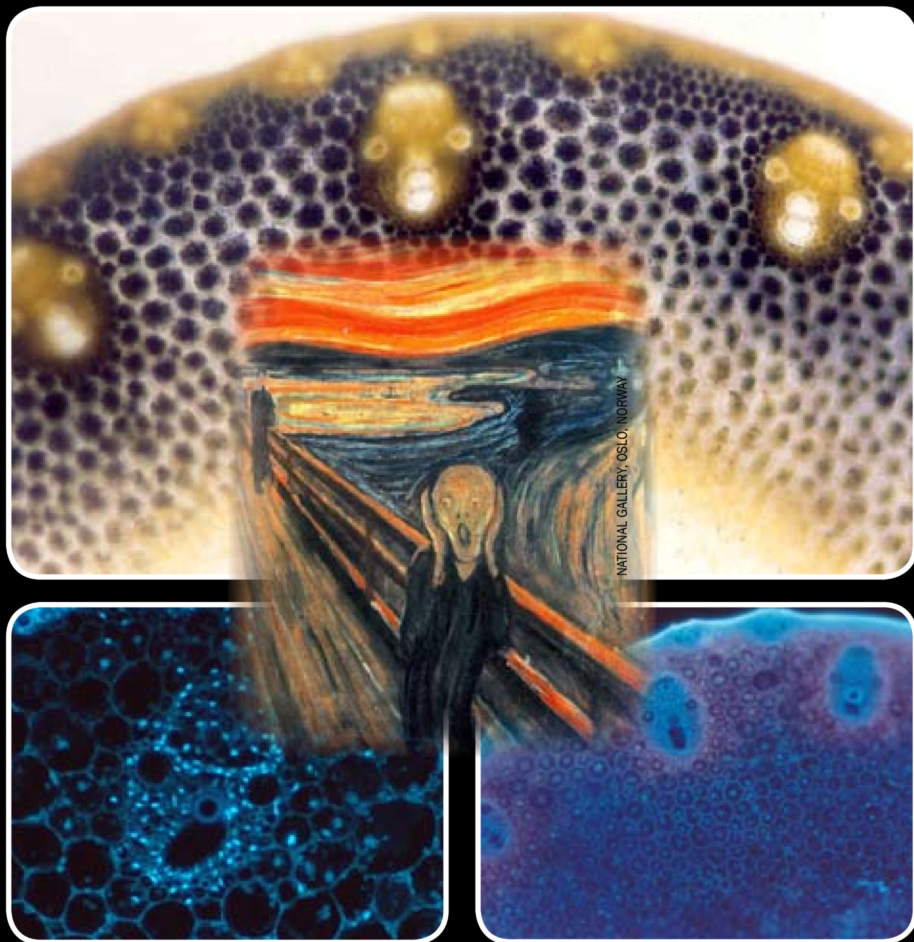
"Scientists are basically storytellers; we have to tell convincing stories. Musical and theater performers are storytellers too. I enjoy the task of converting a written word into an entertaining experience."

His own words best encapsulate who John Bennett is and what he does. Since 1992, as senior scientist at the International Rice Research Institute (IRRI), he has been using biotechnology and molecular biology to work on challenges ranging from insect resistance to drought tolerance. At the same time, he has mentored Ph.D. students, sung as a member of the IRRI choir, and acted in plays and musicals with his IRRI colleagues.

Dr. Bennett finds all of these very fulfilling, but mentions that sharing his expertise through teaching is perhaps the source of greatest satisfaction.

"One joy for me is working with students from the Philippines and other countries, including China, Vietnam, India, Bangladesh, Pakistan, Iran, and Nigeria," he says. "These students have made a major contribution to the work of my group, although they would be the first to say that the Philippine staff here has made a major contribution to their work. It is very nice that we can have students come to IRRI and find a team of people willing to help them, the Philippine staff—who also learn a lot from the students."

Listening to his many stories about his life at IRRI, Dr. Bennett's passion for teaching



RICE TO MAKE you scream: cross-sections of the uppermost internode of the rice stem, known as the peduncle, mimic the face in Edvard Munch's 1893 painting, *The scream*.

is obvious. The wisdom he imparts is delightfully candid.

"There are two aspects in my philosophy of doing science, which I tell to my students: if a thing is worth doing, it's worth doing well; but if a thing is worth doing, it is also worth doing badly," he relates with a spark in his eyes.

"For example, if you wanted to learn to ride a bike, you expect to fall off the bike, right? You expect to ride it badly. But it's worth learning because it will make things more efficient and easier for you later. Similarly, in understanding a complex biological system such as a drought-stressed rice plant, many of the experiments that we would like to do are too complicated. There's a certain skill in knowing how to initially simplify a complex system in an illuminating way."

For a number of years now, Dr. Bennett has given incoming students a list of 10 things that they should expect to learn. Through the years, these 10 things (see box, *right*) have served as a compass that guides students in their learning—a consistent and simple list for the students to help them prioritize their tasks and organize their time.

"Time is their enemy, not the supervisor," insists Dr. Bennett, "so being able to organize their time is very, very important. However, I try to make sure they don't spend the whole time in the lab; I'm very happy if they go out and do other things."

When he's not in his lab absorbed in molecular biology, Dr. Bennett is out there doing "other things" himself—onstage, acting in an IRRI play, singing with gusto with the IRRI choir, or at home, reading novels to his wife and mother, a pastime he relishes.

"During my first Christmas at IRRI, in 1992, I was really excited to see *Snow White and the Semi Dwarves* [a play on "semidwarf," the type of modern high-yielding rice variety that drove the Green Revolution in Asia]. For 4 or 5 years, we had these very enjoyable plays."

In 1994, Dr. Bennett played the role of sultan in the IRRI play *Aladdin and the Forty Thieves*. More than a decade later, one of his co-stars, plant pathologist Robert Zeigler, would become the institute's director general. "I had three very beautiful daughters; one daughter was named Jasmine, one was Japonica, and the third was Indica, played brilliantly by Dr. Zeigler."

Dr. Bennett also enjoyed singing in the IRRI choir—including at the 1995 visit of then Philippine President Fidel Ramos, for whom they sang the Philippine national anthem.

Sharp, energetic, committed, and talented, Dr. Bennett seems unstoppable, be it in his science or in his art. Not even his bout with cancer back in 1999 could dampen his spirit and zest for life.

"Having cancer just made me more aware of how much cancer there is in the Philippines," he explains. "I became much more involved, much more aware of what's happening with IRRI staff and their families in that respect."

Prior to IRRI, Dr. Bennett worked at the International Centre for Genetic Engineering and Biotechnology in New Delhi, where

The (scientific) world according to John

Dr. Bennett's list of 10 fundamental skills for rice research, which Ph.D. students should master by the time they finish their study:

1. Become more fluent in written and spoken English
2. Understand the rice plant in the context of your research
3. Understand the scientific literature in the same context
4. Understand and master techniques needed in this context
5. How best to organize your time
6. How best to work with other people
7. How to design a research program
8. How to design an experiment
9. How to write a scientific paper
10. Understand the scientific method, especially statistical analysis and replication of data, and the formulation and testing of hypotheses.

he and his team looked at insect resistance using marker-aided selection (a technique that allows researchers to rapidly search for candidate plants that possess a gene for a desired trait) and genetic engineering—two approaches that IRRI was developing too.

“In 1991, some scientists from IRRI visited my lab in India,” he recalls. They must have liked what I was doing there and they thought it would be nice to have me come to IRRI. Working in India for 3 years was very, very exciting but it was very attractive to be able to come to a place which conducts rice research across the whole board, from social sciences to genetics to natural resource management. And not to forget things like the library and historical records of rice, and the wonderful tradition—it seemed like an opportunity not to be missed.”

Thus began his career at IRRI, which is highlighted by an impressive list of research achievements. From 1992 to 2000, Dr. Bennett’s work on insect resistance allowed his team to map rice genes for resistance to Asian rice gall midge. Through marker-aided selection, the genes were used to develop varieties with enhanced gall midge resistance in Chhattisgarh, Andhra Pradesh, and Tamil Nadu (India), and Guangzhou (China). His research on disease has resulted in rice with increased resistance to sheath blight fungus and bacterial blight.

One of Dr. Bennett’s most challenging, and potentially rewarding, areas of research has been his work on apomixis—a trait, seen in other cereals but not rice, that allows seed formation without fertilization. Achieving apomixis in high-yielding hybrid rice varieties would allow farmers to reuse hybrid seed rather than purchase new seed each season, thereby decreasing the cost and increasing the flexibility of hybrid rice production.

More recently, Dr. Bennett has turned his attention to unraveling the secrets of why rice plants are susceptible to drought and heat, two environmental stresses that devastate rice farms across the globe every year.

“Drought is associated with both water deficit and heat stress,” he explains. “I enjoy studying the elongation of the topmost joint of the stem—the peduncle. It grows at a phenomenal 6 to 12 centimeters a day, but growth stops under water deficit, leaving the panicle sterile and trapped within the top leaf. We’re using microscopy and molecular analysis to identify whether drought stops cell division, cell elongation, or both, and which varieties are better than others at this process under stress.

“As far as heat stress is concerned, we know that plants are vulnerable to heat when they open their flowers. I was fascinated to see that the heat-sensitive variety Moroberekan opened its flowers between 10 a.m. and noon, when temperatures are high, whereas the more heat-tolerant variety IR64 opened its flowers between 8 a.m. and 10 a.m. We are looking at the genetic basis of this difference in opening time to see if it explains the difference in heat sensitivity.”


IRRI

ENHANCING INSECT RESISTANCE: Dr. Bennett, in his paper coveralls, inspects a new transgenic plant.


CRISSAN ZEIGLER

THEATRICAL FLAIR: Dr. Bennett (*right*) and IRRI Director for Program Planning and Communications Mike Jackson, then head of the Institute’s Genetic Resources Center, as, respectively, King Richard the Lionhearted and Prince John in a 1997 IRRI production of *Robin Hood*.

After IRRI, Dr. Bennett has no plans for an idle retirement. “Molecular biology is a very rapidly developing field,” he says. “Young people coming into the field have to learn a lot of molecular biology, both practical techniques and the theory underlying it, but we are falling behind a little bit in linking this molecular biology with other sorts of biology, particularly physiology. In my retirement, I want to explore systems biology, where different levels are integrated.”

Dr. Bennett grew up in Sydney, Australia, and will divide his time between Sydney and his wife’s hometown of Colombo, Sri Lanka, after he finishes at IRRI in December. But his home for the past 15 years, Los Baños, Philippines, will not be forgotten.

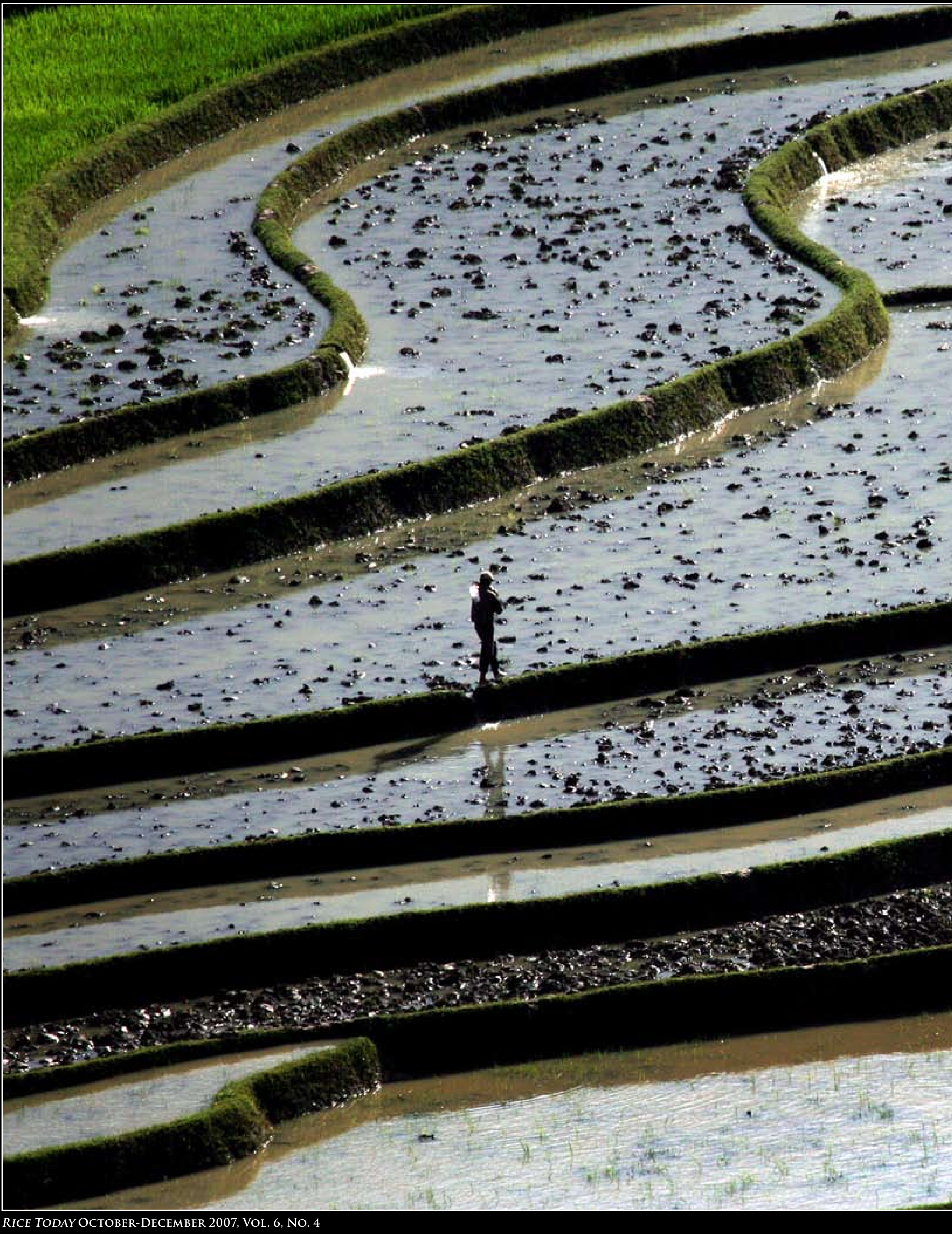
“Life has been very nice here. We’ve really enjoyed being with the Filipino people; it was a brilliant idea to put IRRI in the Philippines.”

Like a child promised a reward after hard work, Dr. Bennett looks forward to the day when he can sit back and look after the three “mothers” in his life—his wife, his mother, and his mother-in-law. He recites the question he will delight in: “Would you like a book to be read to you?”

It is, of course, a question that will be met with a resounding “yes!”

With a big smile, Dr. Bennett says that “Reading to someone, be it science or art, is a way of sharing. When you’re reading a book to yourself, you don’t immediately share it; if you’re reading to someone else, you share it with them immediately.”

Ariel Javellana



In the mountainous areas of northern Vietnam, terraces allow farmers to control irrigation and grow more rice.

A HYBRID RICE yield trial in Jiangxi, China.

Hybrid rice has helped China feed one-fifth of humanity and avoid mass hunger. **Rice Today** ***investigates the international collaboration behind this history-altering technology.***

A hybrid history

RODOLFO TOLEDO (2)

by Adam Barclay

A country that is home to around one-fifth of the entire planet's population faces some serious challenges. Perhaps the most fundamental of these is the question of how it feeds itself. Ensuring enough food for 1.3 billion stomachs is, to say the least, extraordinarily difficult. But it is something that, over the past few decades, China has done remarkably well.

One of the reasons for China's recent food-security success is its impressively high rice yields. In the midst of much hunger and starvation in the 1960s, it was clear the country needed to boost its agricultural output. Now, at an average of more than 6 tons per hectare, China's yields are higher than those of most of its neighboring countries. There are many reasons for this, but one in particular is the way that the country has not only embraced hybrid rice but also become the world leader in its research and development.

In conventional rice varieties, each flower contains both male and female organs, allowing the plant to reproduce itself through self-pollination (inbreeding). Hybrid rice seeds, however, are produced from crossing two genetically different parents. This results in the phenomenon of heterosis—commonly known as hybrid vigor—and the consequent higher yields.

THE FLOWERS of a modern rice plant (*Oryza sativa*).

ROWENA OANE

Hybrid vigor is expressed during the plant's early vegetative and reproductive growth stages. Young hybrid seedlings have faster root and leaf-area development and better canopy development; the mature plant has increased total dry matter, larger panicles (the terminal shoots of a rice plant that produce grain), more spikelets (units of the rice flower) per unit area, increased total weight of grains, and, consequently, higher yields.

The downside is that farmers need to buy new seeds each season. The grains produced by inbred varieties are almost genetically identical to their parents and so can be saved and planted later. If a farmer tries to plant the genetically diverse seeds (produced by sexual reproduction) saved from a previous hybrid crop, the resultant plants will display widely varying traits, in much the same way that human siblings look different. The ensuing crop will be an inconsistent, low-yielding disappointment.

Although the first paper on the application of heterosis to rice production was published way back in 1926, China was the first country to seriously investigate the technology's potential. Led by "father of hybrid rice" Longping Yuan, director general of the China National Hybrid Rice Research and Development Center (CNHRRDC), research began in earnest in 1964. Prof. Yuan received the World Food Prize in 2004 for his efforts.

The Chinese researchers realized that, to produce commercially viable hybrid varieties, they would actually need three breeding lines—not simply two parents. These are known as the male-sterile line, the maintainer line, and the restorer line (see figure on page 25).

The male-sterile plant does not produce pollen itself, but accepts pollen from other plants, thus allowing a hybrid. In the late 1960s, the Chinese hybrid team scoured the country for naturally occurring (wild rice) male-sterile plants, eventually finding such a species in 1970 on Hainan Island.

When they tried to cross this species with a range of commercial Chinese varieties, the researchers found that almost all the commercial varieties acted as maintainer lines. This meant that, if they were crossed with the male-sterile line, the next generation (known as the F_1 generation) would also be male-sterile, and would be similar to the original male-sterile parent. As its name suggests, the maintainer line is therefore used to maintain a male-sterile line.

FORMER IRRI senior scientist and hybrid rice research leader Sant Virmani.

So far, so good. It was at this point, though, that the research hit a wall. The scientists had a male sterile line, which could accept pollen from other plants. They had a maintainer line, which would allow a continuous supply of male-sterile seeds. But they didn't have a restorer line—any cultivar that restores fertility in the F_1 generation when crossed with a male-sterile line and, hence, can be used to pollinate the male-sterile parent and produce hybrid rice seeds that can be used in farmers' fields.

"FATHER OF HYBRID RICE" Longping Yuan (*right*) talks to Gerard Barry, leader of IRRI's rice and human health program, during a visit to the Institute in 2004.

ARIEL JAVELLANA (2)

The potential of hybrid rice was threatening to remain just that—potential. Fortunes changed in 1970, however, when germplasm (seeds and the genetic material they contain) from the International Rice Research Institute (IRRI) was first sent to China for breeding inbred varieties. According to IRRI hybrid rice breeder Fangming Xie, it was a eureka moment: "They tested the IRRI lines to see if they could act as restorer lines, and bingo—got it!"

For farmers to make a worthwhile investment in hybrid seeds—which can be used for only one season—they need to produce a yield at least 15%

higher than that of the farmers' best available inbred variety. Dr. Xie, who obtained his master's degree at CNHRRDC as a student of Prof. Yuan, says this was another area in which the IRRI germplasm helped springboard China's hybrid rice program. Because the IRRI germplasm was relatively genetically different from the Chinese maintainer lines, it prompted sufficient heterosis to boost yields to the required level. As a bonus, the IRRI lines were more resistant to pests and diseases than the Chinese varieties.

"Without IRRI germplasm, the success of hybrid rice in China would have been much delayed," says Dr. Xie. In fact, pedigree studies have shown that 90% of the restorer-line donors for Chinese hybrid rice varieties came from IRRI.

HYBRID RICE in Brazil.

FANGMING XIE

Since those early days, many IRRI lines have been distributed to China for use in hybrid rice development, and scientist exchange between the Institute and China has boosted research capacity on both sides. The contribution goes both ways, too—China has provided expertise to IRRI, along with several varieties for the development of promising male-sterile lines suitable for tropical and subtropical areas.

Only after China's initial success with IRRI germplasm did IRRI start its own hybrid program in 1972, led by retired plant breeder Sant Virmani. But, in the face of skepticism from some scientists, the Institute halted its research the following year, only restarting it in 1979 after China had fired up international interest by commercializing the technology.

"I had always known hybrid rice was technically possible," explains Dr. Virmani, who left IRRI in the early 1970s but returned a decade later to again lead hybrid research there. "Seeing its widespread adoption in China in the late 1970s convinced me that it was a serious and important option for the rest of the world's rice farmers."

IRRI hybrid rice breeder Fangming Xie.

ARIEL JAVELLANA

Unsuited to the tropics because they lacked disease resistance, the Chinese varieties were not viable for farmers across much of tropical Southeast Asia. More work was needed to develop hybrid rice varieties that would thrive in the region's hot, humid climate. Thanks to the efforts of Dr. Virmani, who retired in 2005 (see *A hybrid pioneer* on pages 28-31 of *Rice Today* Vol. 4, No. 2), IRRI now has a vibrant hybrid rice research program and many countries in Southeast Asia have established, and are expanding, their hybrid rice production.

Apart from Vietnam, India, and the Philippines, which have commercialized hybrid rice for some time, countries such as Bangladesh, Indonesia, and Pakistan have achieved recent success with hybrid rice. The Asian Development Bank–funded collaborative project *The Development and Utilization of Hybrid Rice in Asia*—managed by IRRI with participation from CNHRRDC and the China National

Rice Research Institute—has brought Chinese experts to South and Southeast Asian countries to further develop the hybrid rice seed industry and the necessary production techniques. In turn, trainees from these countries have received hybrid rice training in China.

Under Dr. Xie, IRRI is continuing to develop hybrid rice products and disseminating IRRI germplasm to rice-producing countries and to the private sector. The Institute also conducts training in seed production and breeding, and helps other countries develop plans and policy support for hybrid rice programs.

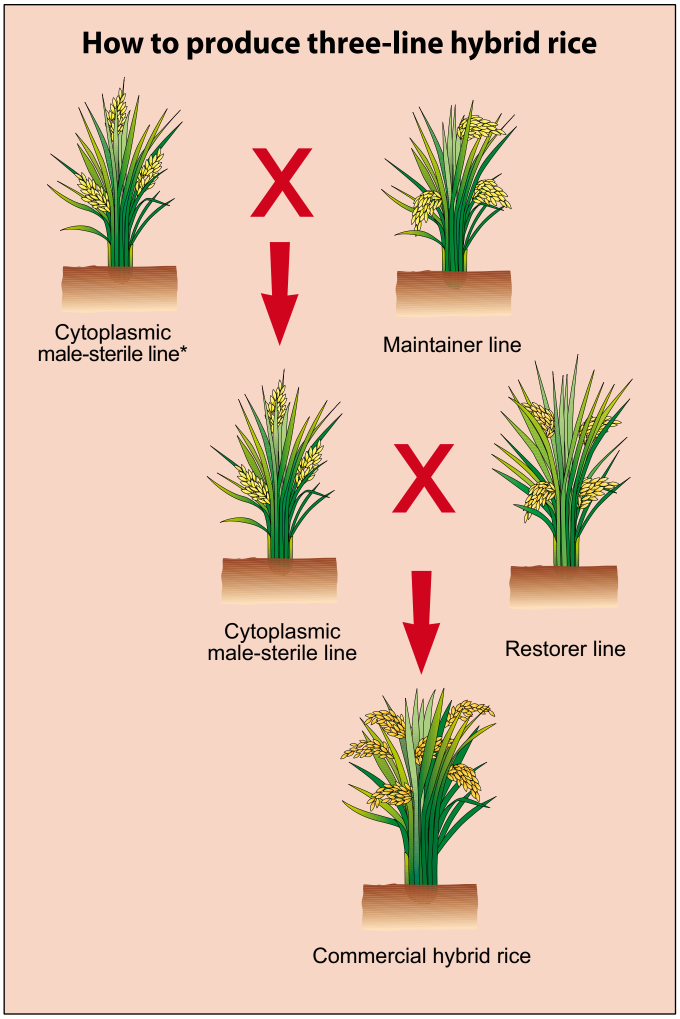
Due to farmers' need for new seeds every season, the private sector—which produces 99% of commercial hybrid rice seed—necessarily plays a key role in the hybrid rice industry. Public institutions perform much of the research and breeding, and develop the products, which are then transferred to the private sector for marketing and seed distribution.

Although already strong, the hybrid rice industry in China continues to grow. Currently, Chinese hybrids, which have an average 15–20% yield advantage over inbreds, are planted on around 16 million hectares—more than half of China's total rice area of 28 million hectares.

China grows both of the main subspecies of commercial rice, japonica (sticky) and indica (less sticky). Indica is grown in the southern and central latitudes; japonica is grown in the north. In general, people prefer japonica over indica because of its higher grain quality, but japonica prices are higher. About 85% of China's indica rice is already hybrid, so current efforts to increase hybrid production are focused on boosting the proportion of japonica hybrid rice, which presently makes up only 3% of total japonica area. The Chinese government is aiming for 70% of all China's rice to be hybrid within 5 to 8 years.

Chinese researchers are also continuing to develop what are known as two-line hybrids. Most of the current varieties require three lines—male-sterile, maintainer, and restorer. Two-line hybrids, although still variable from year to year, don't need a maintainer line and outyield three-line hybrids. After successful commercialization in 1995, the area planted to two-line hybrid rice had reached 1.6 million hectares, or 10% of the total hybrid rice area, by 2003.

So-called super hybrid rice varieties are two-line hybrids produced from more diverse parent rice lines. The relatively large genetic difference between the parents causes greater heterosis and, therefore, even greater yields (a 10% yield advantage over three-line hybrids, or a 30–40% advantage over inbred varieties).



*A *cytoplasmic* male-sterile line is the type of rice line required for the production of three-line hybrid rice varieties.

In a paper entitled *The second generation of hybrid rice in China*, published in the Proceedings of the 20th Session of the International Rice Commission (Bangkok, Thailand, 23–26 July 2002), Prof. Yuan said, "If super hybrid rice covers an annual area of 13 million hectares in China, and calculating a yield increase of 2.25 tons per hectare, it is expected that the annual increased grains will reach 30 million tons, which means 75 million people more can be fed every year."

The higher yields of hybrids can come with a cost, though. Grain quality in the first generation of hybrid rice varieties was often lower than that of inbreds. Chalkiness can also be a problem. High-quality hybrid rice seed is available, but at a higher cost. However, quality has improved in recent years and two-line hybrids are expected to further enhance hybrid eating and cooking characteristics.

In *Hybrid rice for food security in the world*, a paper presented at the United Nations Food and Agriculture Organization's (FAO) 2004 Rice Conference, Prof. Yuan said that "hybrid rice has been playing a critical role in solving the food problem of China, thus making China the largest food self-sufficient country .... I firmly believe that hybrid rice, relying on scientific and technological advances and the efforts from all other aspects, particularly from FAO and IRRI, will have a very good prospect for commercial production and continue to play a key role in ensuring future food security worldwide in the new century."

Relocating rice production in China

by Robert Hijmans

Between 1979 and 2005, rice area in China decreased from 32.4 to 28.8 million hectares. At the same time, average yields went up from 4.2 tons per hectare in 1979 to about 6.3 tons per hectare in 1997 and thereafter. Because of these opposite trends, annual Chinese rice production has been fairly stable at 170–190 million tons since 1983.[1] But this apparent stability conceals major shifts in the location and cropping patterns of rice in China.

"Stable rice production conceals major shifts in the location and cropping patterns of rice in China"

Rice cultivation in China is moving northward (see Map 1). From 1979 to 2005, the southern province of Guangdong lost half its rice area, a decrease of 85,000 hectares per year. Over the same period, the northeastern province of Heilongjiang gained 64,000 hectares per year. Together, the four northern provinces of Liaoning, Jilin, Nei Mongol, and Heilongjiang had 2.7% of the Chinese rice area in 1979 and 11.5% in 2005. These provinces have also seen relatively strong increases in yield. In Heilongjiang, for example, yields have gone up 150 kilograms per hectare per year—almost twice the annual yield gain for the whole of China.

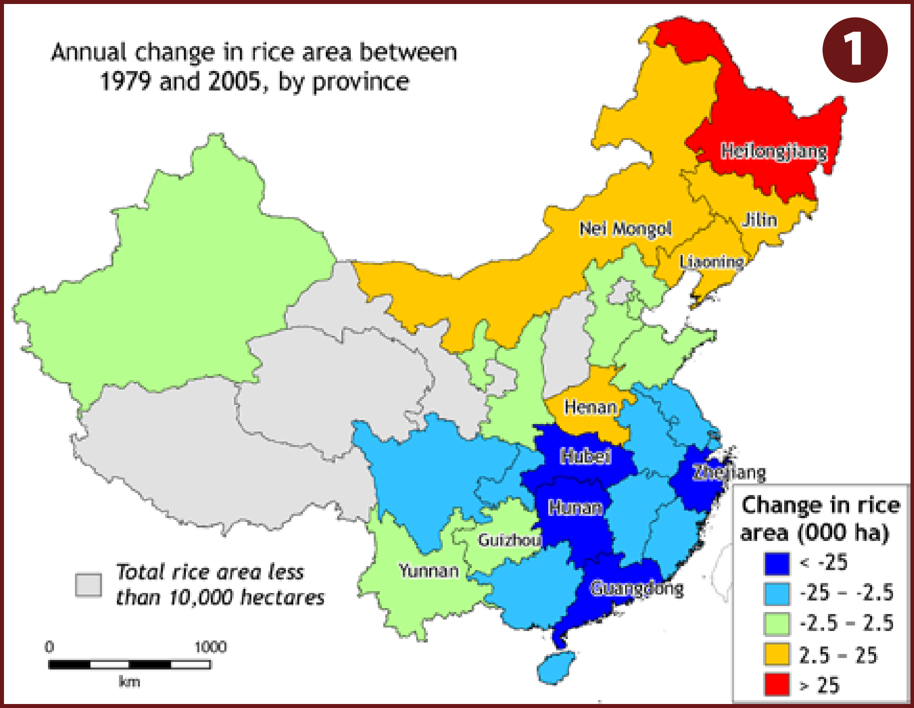
Economic development has strongly contributed to the decrease in rice area in the south. Because of an increased demand for off-farm labor, double cropping of rice—only possible in southern China—is being replaced by a more labor-efficient single rice crop. Some of the land and labor that were used for rice production are now used to produce high-value vegetable crops catering to wealthier consumers who have diversified their diet and eat less rice. Other rice lands have been used for construction.

The decline in rice area in the relatively poor southwestern provinces of Guizhou and Yunnan has been much less than that of other southern provinces. However, economic development does not seem to explain the increase in rice production in the northeast. The main income gradient in China (Map 2) is from east to west and not from north to south.

The increase in rice area in the north may be related to an increased demand for japonica-type rice, which is better adapted to temperate climates, or to an expansion of irrigation infrastructure. Another factor that may have contributed is climate change. Since the mid-1960s, Earth has experienced very strong global warming of about 0.03 °C per year.[2] Warming has been strongest at high latitudes, and minimum temperature has increased more than maximum temperature. Warming in northeast China has been particularly strong (Map 3). The average minimum temperature in Heilongjiang is now about 2.5 °C higher than it was in the early 1960s!

A yield decline associated with increasing minimum temperatures has been observed in long-term trials at the International Rice Research Institute in the Philippines.[3] But, in relatively cool areas such as Heilongjiang, warming may have contributed to higher yields through a longer growing season and reduced cold stress.

Only a few studies have analyzed the influence of past climate change on crop production.[4] A challenge in

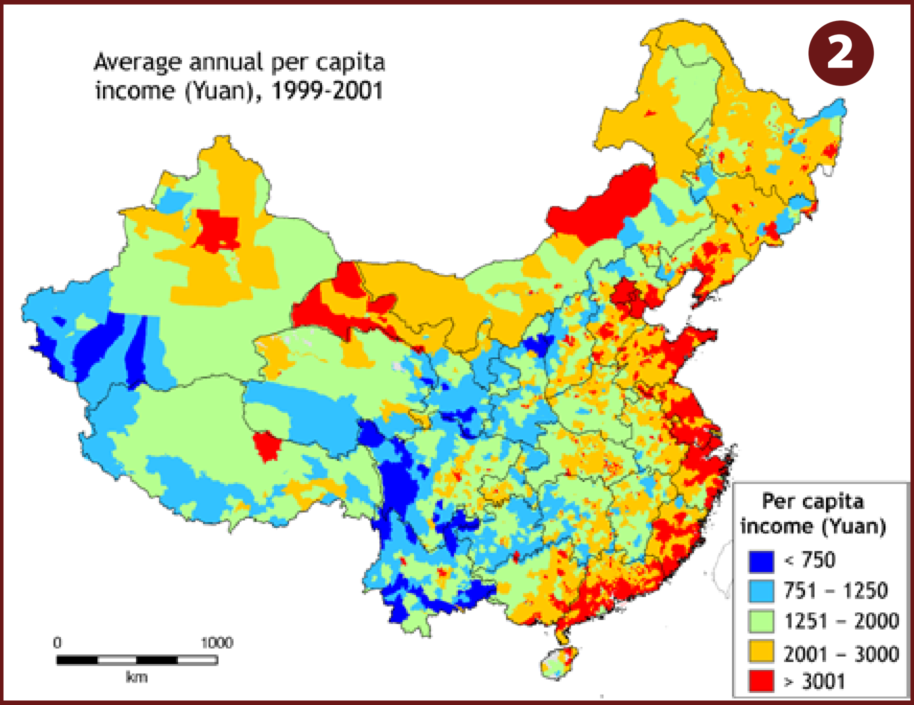


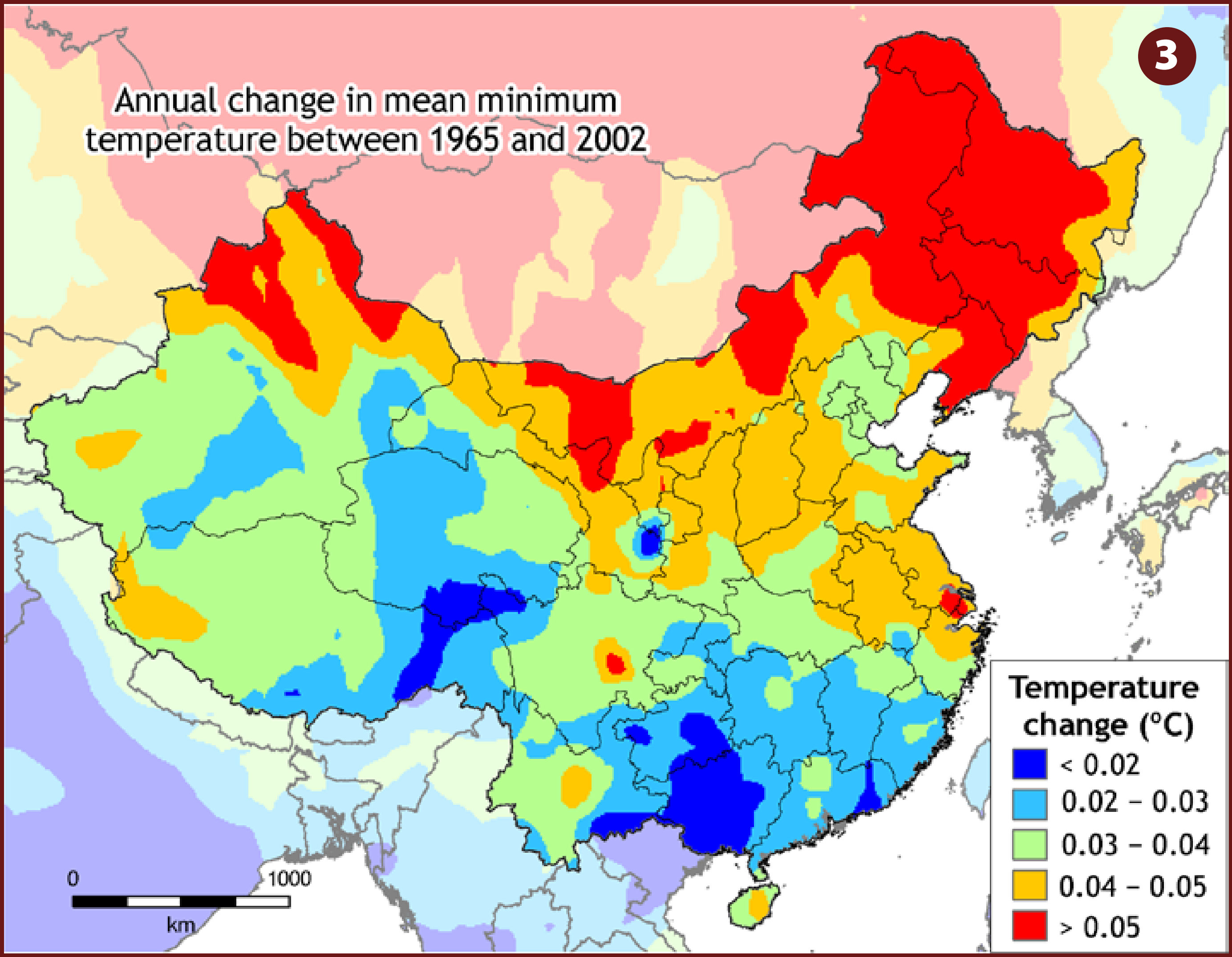
[1] Data available in the World Rice Statistics database at www.irri.org/science/ricestat.
[2] Global average, only considering temperatures over land, excluding Antarctica. Estimate based on data by Mitchell and Jones (2005), International Journal of Climatology 25:693-712.
[3] Peng et al (2004). Proceedings of the National Academy of Sciences USA 101:9971-9975. www.pnas.org/cgi/content/full/101/27/9971.
[4] Examples of such work include You et al (2005), Environment and Production Technology Discussion Paper 143, IFPRI. www.ifpri.org/divs/eptd/dp/papers/eptdp143.pdf, and Lobell and Field (2007), Environmental Research Letters 2:014002. www.iop.org/EJ/article/1748-9326/2/1/014002/erl7_1_014002.html.

such analyses is disentangling the role of climate change from that of other factors influencing land use. For example, although warming increases the potential for double and triple cropping of rice, prevailing economic conditions are nudging farmers in the opposite direction.

The spatio-temporal coincidence of warming and rice area expansion in northern China is striking, but a much more refined analysis is necessary to assess whether warming is contributing to this expansion. In areas such as northern China, which have witnessed rapid climate change over the past decades, looking backward can improve our ability to predict the future.

Dr. Hijmans is a geographer in IRRI's Social Sciences Division.





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RICE BREEDER Huaqi Wang surveys his aerobic varieties in a China Agricultural University experimental field.

As Chinese farmers face a worsening irrigation crisis, they need a way to grow rice with less water. Aerobic rice may be the answer.

High and

Story and photos by Adam Barclay

On a steaming hot Beijing day in August 2007, a group of researchers from China Agricultural University (CAU) visited their experimental station on the edge of the gigantic city. Several hectares of what has come to be known as aerobic rice—grown like any other nonrice crop, in unflooded fields—stood oblivious to the brutal, unforgiving sun.

This is why *Rice Today* was in China. The push to establish a large-scale aerobic rice production system, which achieves high yields using a fraction of the water required for flood-irrigated rice (known simply as lowland rice), is gaining momentum. There are wrinkles to be ironed out, but the potential, in the face of widespread and ever-worsening water availability, is enormous.

On this day, though, it wasn't the aerobic rice that grabbed our attention. As we climbed into the car to head back to the university campus, Huaqi Wang—the breeder responsible for the several aerobic rice varieties we'd inspected—turned to us.

"Before we return, I want to show you something," said Prof. Wang, director of CAU's Upland Rice Research Center.

Without any explanation, we drove to another rice field, a few kilometers away. This half-hectare of healthy looking rice, belonging to a

dry

local farmer, represented something truly momentous. It was the last remaining plot of commercial lowland rice in the municipality of Beijing.

With a wry laugh, Prof. Wang told us that soon it would be gone too, muscled out by a still rapidly growing population and fast-encroaching urban and industrial works, whose prodigious hunger for land and thirst for water mean that there simply isn't enough of either for lowland rice.

CAU water expert Xiaoguang

ARIEL JAVELLANA

MAKING A POINT about aerobic rice: IRRI water scientist Bas Bouman.

Yang, who researches water-saving agricultural technologies, says that the water situation, especially in northern China, has become desperate. "In Beijing," she says, "the groundwater depth is very low—at least 20 meters below the surface and dropping further every year."

Beijing, in China's north, is home to more wheat and maize than rice, but the field in front of us symbolized not only a dying practice but also the promise of water-saving technologies like aerobic rice. Perhaps, we lamented, it should be preserved as a museum exhibit.

According to Prof. Yang, as recently as 10 years ago, a lot of lowland rice was grown in Beijing. "Now," she says," apart from this field, there's none. But people here want rice—therefore, we need aerobic rice."

When water is scarce, rice is inevitably the worst-affected crop. Compared with the world's other major staples, wheat and maize, rice uses around twice as much water—roughly 2,000 liters to produce a single kilogram.

Plant nutritionist Shan Lin, from CAU's Department of Plant Nutrition, points out just how thirsty lowland rice is. "In China, 70% of water is used in agriculture; 70% of that is used in rice production," he says. "In terms of rainfall or irrigation water, lowland rice needs approximately 1,000–1,500 millimeters. Aerobic rice needs around 600 millimeters. Aerobic rice can really help us save water."

Bas Bouman, senior water scientist and aerobic rice work-group leader at the Philippines-based International Rice Research Institute (IRRI), is acutely aware of this problem. When he arrived at IRRI in 1999, Dr. Bouman had an idea: why can't we grow rice as an irrigated but unflooded dryland crop, like wheat or maize? There already existed upland rice crops—traditional varieties that yield poorly but are able to cope with extremely harsh conditions, including very dry climates, poor soils, and often sloping land. What if the sturdiness of upland rice could be combined with the high-yielding traits of lowland rice?

So, in 2000, Dr. Bouman started asking agronomists and plant physiologists about the idea.

"The answer I always got," he says, "was, 'It's just not possible—rice is not like that, rice is different.' So I parked the idea for a while, until I learned about the work to improve upland rice in more favorable environments. There were people at IRRI with basically the same idea, but not in the irrigated lowland environment. They were working in the sloping uplands, trying to improve upland rice."

Like most good ideas, aerobic rice was, in theory, fundamentally simple. It also turned out that it wasn't the first time somebody had thought of it. The IRRI upland researchers introduced Dr. Bouman to Prof. Wang, who, at that time, had been

ANHUI PROVINCE farmer Guangyun Dai shows off one of his aerobic rice plants.

working on aerobic rice for more than a decade. Sure enough, he had crossed hardy upland rice varieties with modern lowland varieties.

"I realized that what Prof. Wang was doing was exactly what I had in mind and that, yes, it *is* possible," recalls Dr. Bouman.

Prof. Wang's progress was encouraging—despite very little research support, he claimed to have achieved yields of above 6 tons per hectare. He was working in low, flat areas where farmers have insufficient irrigation to flood the field, but have access to enough water for two or three small irrigations per season or as much rainfall as is needed for wheat or maize. This, says Dr. Bouman, is precisely the target zone for aerobic rice. In water-scarce China, it is an environment growing in area every year.

For farmers who have been forced by lack of irrigation to end their lowland rice production, aerobic rice offers the chance to grow rice once more. Rice is so fundamentally important to the diet of most Chinese people that farmers will go to great lengths to grow rice for themselves and their family, even if it means sacrificing income that would allow them to buy rice on the market. It is a cultural as much as an agricultural decision.

"When we say, well, you can also buy it on the market," says Dr. Bouman, "they look at you and say, 'yes, that's fine, but I want it in my backyard.'"

And, another factor further boosts the potential of aerobic rice. Although rainfall in many parts of China is high, it is also very unstable. In such areas, the majority of the year's rain can fall over a couple of months in summer, causing floods that badly damage or totally destroy traditional dryland crops such as maize and soybean. Aerobic rice, though, can still handle flooding. In a year when rainfall is spread out and no floods occur, a maize crop will yield higher than an aerobic rice crop. But, if the floods hit—and they often do—aerobic rice will give farmers a few tons per hectare, where maize would have left them with nothing.

The day after witnessing Beijing's last field of lowland rice, *Rice Today*, with CAU agronomist Guanghui Xie, headed south to Anhui Province, where rice is a much more important crop (see map, *above right*). The farmers in Anhui are some of China's poorest—any technology that can increase their water productivity and help them secure rice for their own consumption can also help reduce poverty.

Anhui, like Beijing (and much of northern China), is also facing a water crisis. Here, too, the pace of urban and industrial development is staggering and the flow-on effects for farming are sobering indeed. Rivers have been diverted to provide water for cities, groundwater is dropping every year, and laborers are leaving the farms in droves to find better-paid work in mining and construction. Compounding the problems, much of the province's irrigation infrastructure is outdated and in bad need of maintenance.

The worsening shortage of farm

THE SUN SETS over Hefei; a new power station overshadows rice fields (*right*) in Fengtai. Rapid, large-scale urban and industrial development is pushing laborers off the farms and into the cities. The consequent rising cost of rural labor makes aerobic rice, which requires less labor than lowland rice, more attractive.

Aerobic believers

Although many farmers are impressed by aerobic rice's potential, most would opt for lowland (flood-irrigated) rice—and its significantly higher yields—if they had the choice. But, as water becomes scarcer and more and more farmers lose that choice, aerobic rice is becoming an increasingly important technology.

Two neighboring villages in Fengtai County, Anhui Province, offer a graphic illustration of the difference between farming with and without plentiful access to water. Xiwang and Cuihai villages may share a boundary, but they don't share water.

In 2000, the irrigation system that fed Cuihai from the nearby river ceased to operate. Xiwang, meanwhile, has a functioning irrigation system that delivers enough water for lowland rice production.

At the village boundary, Xiwang's lowland rice crops stand side by side with Cuihai's aerobic rice fields. The aerobic rice is doing well at this stage of the 2007 season, but, until varieties and crop management systems improve further, it can't compete with the lush, green lowland rice.

CHUNQIAO WANG (*left*) and Chunjian Wang examine their aerobic rice crop. In the background are their maize crop and a lowland rice crop belonging to a farmer from the neighboring village.

Three farmers from Cuihai—Chunguo Wang, Chunjian Wang, and Chunqiao Wang—would love to have access to Xiwang's irrigation, but they're not complaining. Before 2000, all three grew lowland rice. The next 2 years, with no rice in their fields, their maize crops were flooded and returned very low yields. In 2003, they heard about aerobic rice from a local agricultural technician and were immediately interested.

SHAOBING PENG

AEROBIC RICE FARMERS (*from left*) Chunjian Wang, Chunguo Wang, and Chunqiao Wang.

With the other village farmers, the three men started growing aerobic rice in 2004. The village's combined aerobic rice area that year was 35 mu (2.3 hectares). In 2006, it climbed to 50 mu (3.3 hectares). When *Rice Today* visited Cuihai in August, the 2007 crop was looking good, and the farmers were expecting a yield of around 350 kilograms per mu (5.25 tons per hectare). If this prediction holds, the village may plant 150 mu (10 hectares) in 2008.

In July and August of 2007, the maize crops were again hammered by heavy rain and floods; the farmers expect yields 40–50% lower than in 2006. The aerobic rice, however, withstood the weather unscathed.

Chunqiao Wang is a true aerobic rice believer, renting neighboring farmers' land so he can grow 9 mu (0.6 hectares) of aerobic rice—2 mu more than the total amount of land he actually owns.

"Overall, I feel good about aerobic rice, especially if the yield can reach 400 kilograms per mu [6 tons per hectare]," he says. "The future will be bright if we can get improved varieties. Even if the irrigation improves, if we get improved varieties, I might stick with aerobic rice—it costs much less than lowland rice. If everything goes well, our village can grow more than 200 mu [13.3 hectares] of aerobic rice."

labor and consequent rising labor wages further boost aerobic rice's attractiveness to farmers. Lowland rice, which requires seedlings to be maintained in a nursery and subsequently transplanted, is much more labor-intensive than aerobic rice, which farmers can plant by row-seeding or broadcasting dry seeds.

According to Jianbo Yang, president of the Anhui Academy of Agricultural Sciences, "the labor situation is making aerobic rice very attractive to the farmers in Anhui. Many farmers are willing to sacrifice 50 kilograms per mu [750 kilograms per hectare] compared with lowland rice because of the labor aerobic rice saves them."

JIANBO YANG, president of the Anhui Academy of Agricultural Sciences.

Even without the labor savings, aerobic rice is less expensive than lowland rice. Ding Guangli, head of the Funan County Agricultural Research Institute in Anhui, says that, taking into account agricultural materials only, aerobic rice costs farmers around 3,750 Chinese yuan (US$480) per hectare per season—3,000 yuan ($405) per hectare less than lowland rice. Mr. Ding adds that, 20 years ago, rice was planted on around 30,000 hectares in Funan

CAU WATER EXPERT Xiaoguang Yang discusses aerobic rice with Ph.D. student Liu.

IRRI CROP PHYSIOLOGIST Shaobing Peng and CAU Ph.D. student Jing Yan, who is studying the resource-use efficiency of aerobic rice systems.

CAU PLANT NUTRITIONIST Shan Lin (*left*), Ph.D. student Wei (*center*), and Huaqi Wang.

County. In 2007, the figure stands at about 16,000 hectares, about 20% of which are planted to aerobic rice.

In a 2005 survey among farmers in Kaifeng County, Hunan Province, and Fengtai County, Anhui Province, IRRI economist Pie Moya found that aerobic rice farmers achieved average yields of 4.2 tons per hectare, versus 5.8 tons per hectare for lowland rice. However, aerobic rice received only 2–3 irrigations, versus 10–13 by lowland rice, and was planted in water-scarce areas side by side with dryland crops such as maize and soybean. Despite the lower yield, profits returned from growing aerobic rice, at around $330 per hectare per season, were the same as obtained from growing maize.

AEROBIC RICE CAN withstand heavy rains and flooding that will badly damage dryland crops such as maize or soybean. This field in Mengcheng was hit by severe rains in July and August 2007.

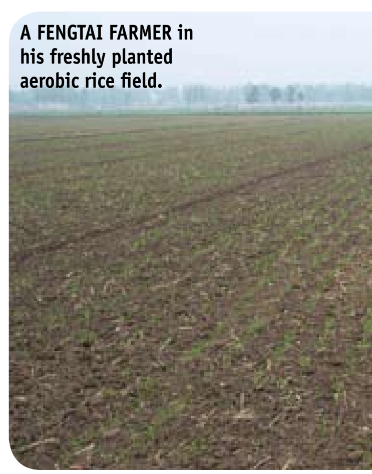
Aerobic rice is still very much an emerging technology, though, and it must be improved if it is to achieve its potential. Prof. Xie is working with farmers in Mengcheng County, Anhui, to develop aerobic rice crop management systems.

Prof. Xie, who first examined aerobic rice in Mengcheng in 2005, says the farmers were initially very interested. The following year, many farmers tried aerobic rice, and, with only a month left before harvest, the crops looked excellent.

“We believed they would yield more than 6 tons per hectare,” recalls Prof. Xie. “But, in the last month, pests and perhaps drought caused poor grain filling and the yield ended up very low. As a result, many of the farmers have stopped growing aerobic rice in 2007.”

Despite 2006’s poor yields, many farmers have persisted with aerobic rice. In Shuanghu village, Mengcheng, of the five farm families who grew aerobic rice in 2006, two quit and three are continuing. Xianming Wu, a 60-year-old farmer who grows rice, maize, and soybeans on 5 mu (15 mu are equal to 1 hectare), is an aerobic rice believer. In 2006, he grew aerobic rice on 1.5 mu, achieving a total harvest of 450 kilograms (equivalent to 4.5 tons per hectare)—more than his neighbors but lower than he had hoped.

So, why did he persevere with aerobic rice in 2007? Unable to obtain enough water for lowland production, Mr. Wu says that it’s very important to him that he can



A FENGTAI FARMER in his freshly planted aerobic rice field.

YANFANG DING (*above*) **weeds her soybean crop. After pests damaged her 2006 aerobic rice crop, she chose not to grow rice in 2007—though wishes she had, with neighbor Xianming Wu's aerobic rice crop (*center*) looking good. *Right*: CAU agronomist Guanghui Xie.**

grow and eat his own rice. Around 20 years ago, he grew lowland rice, but the nearby river that irrigated his fields ceased to provide enough water.

Mr. Wu keeps all the aerobic rice he grows for himself and his family, but if things go well he'd like to start selling some. As a bonus, he and his family prefer the taste and texture of aerobic rice to those of the hybrid rice planted in most flooded fields.

In 2007, things are looking good. Barring another pest outbreak, Mr. Wu predicts 400–450 kilograms per mu (6–6.75 tons per hectare). It's not only the expectation of a good harvest that has him smiling, though. In July and August 2007, Anhui Province was hit by extreme rainfall that caused widespread flooding. This situation forced the national government to open the Wangjiaba dam to relieve flood pressure from the swelling Huai River on urban areas. The resultant flooding caused the temporary relocation of 160,000 people and the loss of huge numbers of crops, for which the government paid compensation.

Shuanghu village residents did not need relocation, but their dryland crops, maize and soybean, were devastated. Mr. Wu expects that his 2007 maize and soybean yields will be less than half his 2006 yields. His aerobic rice, on the other hand, was not damaged by the rains and in the baking August sun still looked strong and healthy.

Shuanghu farmers Yanfang Ding and her husband Jianjun Wu (Mr. Wu's nephew) were not so lucky. They chose not to replant aerobic rice in 2007 and now wish they had. "I'll keep an eye on my uncle's crop," says Jianjun Wu. "If his yield is good, we'll grow aerobic rice again next year."

In Funan County, a different but equally encouraging story is emerging. Here, aerobic rice has exploded in 2007. As we drove through the county, IRRI crop physiologist Shaobing Peng was moved to proclaim that he'd "never seen so much aerobic rice anywhere!"

Funan also suffered heavy rains in July and August 2007 but, unlike Mengcheng, was not hit with a major pest outbreak recently. This, says Dr. Peng, helps explain the apparent aerobic rice boom.

"It's like a battle between aerobic rice and maize, as a summer crop," he explains. "The excessive rain in Funan has helped aerobic rice win that battle. In other counties, the conditions might favor maize for one season, and farmers don't want to risk trying aerobic rice. If we improve aerobic rice varieties and crop management systems, the battle may swing in aerobic rice's favor."

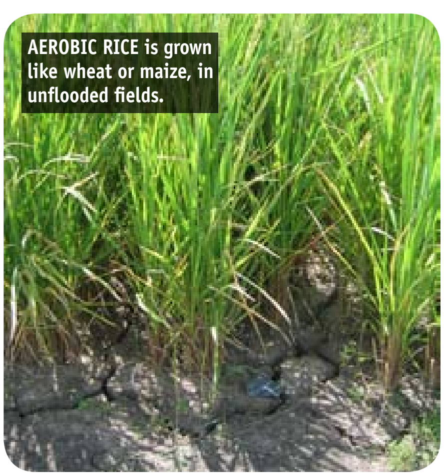
Dr. Bouman says that if this new production system reaches the point where farmers can easily achieve yields of 5–6 tons per hectare, aerobic rice will be a major weapon in the fight against water scarcity and poverty in the scorching North China Plain.

"This scenario is very possible," Prof. Wang says. "As we keep working with farmers, we need to develop new varieties and management systems that include effective weed control, irrigation and fertilizer management, and crop establishment."

Standing at the forefront of aerobic rice development, the farmers of Anhui confirm the scientists' belief that they are on the right track.

IRRI's and CAU's aerobic rice research in northern China is part of the Irrigated Rice Research Consortium and the Consultative Group on International Agricultural Research Challenge Program on Water and Food.

BAS BOUMAN



AEROBIC RICE is grown like wheat or maize, in unflooded fields.

BAS BOUMAN

REN WANG (*right*) looks at NERICA plants with WARDA field technicians Hélaine Diaka (*left*) and Eugenie Gbokede.

R. RAMAN (3)

Three heads are better

In the face of steeply rising rice prices, three of the world's leading international agricultural research institutes plan to combine their activities in Africa and so create a powerful new force focused on boosting African rice production

The signs are ominous across West Africa. The price of rice is rising and, consequently, a groundswell of anger is building in several countries in the region where rice is a staple.

First in Guinea, then in Senegal, Mali, and Côte d'Ivoire, people have taken to the streets to protest against the rising price of rice. In Burkina Faso, Benin, and Nigeria, housewives, restaurant owners, and tradesmen have started to express their discontent. In Guinea-Bissau, people are directly trading goods for rice.

Alarmed by the protests and the sudden increase in newspaper reports on the price hike, the governments of some of these countries have taken hasty measures to bring down the price of rice.

For instance, in Senegal, the second biggest importer of rice in Africa after Nigeria, the government was forced to reduce the price by 20–25 FCFA (US$0.04–0.05) per kilo in July 2007, after consumers' associations in the capital Dakar held two major protest marches.

In Côte d'Ivoire, the 8 August 2007 edition of Abidjan's *Nord-Sud* newspaper reported that the price of rice had risen by 7–22%. A 25-kilogram bag of "Uncle Sam" rice imported from the United States sold for 6,000 FCFA ($12.50) a month ago and is now selling for 7,000 FCFA ($14.50)—an increase of about 7%. The prices of Vietnamese and Thai rice have gone up by 15% and 22%, respectively.

The article also reported that rice wholesalers in Abidjan attributed this sudden price hike to the fall in world rice supply. "This has led to price speculations that are benefiting only the multinationals," wholesalers were quoted as saying.

Economists at the Africa Rice Center (WARDA) have long been worried that Africa would find itself engulfed in a major rice crisis if its rice importation policy were not urgently reviewed. Participants at the June 2007 Third Annual Meeting of the Africa Policy Research and Advocacy Group at WARDA, Cotonou, Benin, also expressed deep concern about the current world rice situation

A WOMAN SELLS rice in Cotonou, Benin.

than one

and its implications for Africa.

According to the US Department of Agriculture's Foreign Agricultural Service, world rice reserves, estimated at 80.6 million tons in 2005-06, are at their lowest level since 1983-84. These stocks represent less than 2 months of consumption and half of the stocks are being held by China alone.

IMPORTED RICE ready for sale in Cotonou, Benin.

World rice consumption continues to outstrip production and the rising prices are expected to double in the next couple of years.

According to the Africa Policy Research and Advocacy Group, established 3 years ago to serve as a channel for transmitting policies to promote the rice sector, the current world rice situation has serious implications for sub-Saharan Africa (SSA) because about 40% of that region's demand for rice is being met by imports. Further, recent analysis by WARDA economists shows that, in West Africa, this figure is even higher, with rice imports covering up to 67% of demand.

"African national rice economies will increasingly become exposed to unpredictable external supply and price shocks," WARDA Economist Aliou Diagne said, highlighting the recent warning by the World Bank that the current rise in cereal prices and the low level of global reserves could unleash widespread food riots in Africa.

Referring to the recent measures taken by some African governments against the price hike, WARDA Director General Papa Abdoulaye Seck said, "It is not possible to continue reducing the price of rice artificially without increasing domestic rice production in SSA. Relying on heavy rice imports is less and less a solution for Africa."

In this context, the recent announcement by three international centers to combine their activities in Africa and so create a powerful new force focused on boosting African rice production has come as a ray of hope for the rice-consuming nations of SSA.

The three centers—all of whom are supported by the Consultative Group on International Agricultural Research (CGIAR)—are WARDA, the International Center for Tropical Agriculture (CIAT) based in Colombia, and the International Rice Research Institute (IRRI) based in the Philippines.

In a joint declaration announcing a major programmatic alignment, the three centers affirmed their commitment to bring the best of science and their experience in Asia, Latin America, and Africa to address the major challenges facing Africa's rice sector.

"By harmonizing our activities, we can cover the whole continent, have a critical mass, address most of the problems facing rice, and at the end of the day we can have a very high impact," commented Dr. Seck.

Among their initial proposals is the establishment of a sub-Saharan Africa Rice Consortium (SARC), which will consolidate the two existing regional rice networks—the West and Central Africa Rice Research and Development Network and the Eastern and Central Africa Rice Research Network. The new combined entity will also cover other parts of SSA that are not members of the existing regional rice networks.

It was agreed that SARC will offer a platform for collective action by the three international centers and collaboration with national agricultural research and extension systems (NARES). SARC will also provide a united front for promoting rice and rice research in SSA and a common conduit for channeling technology and information from international research to NARES and farmers in the region.

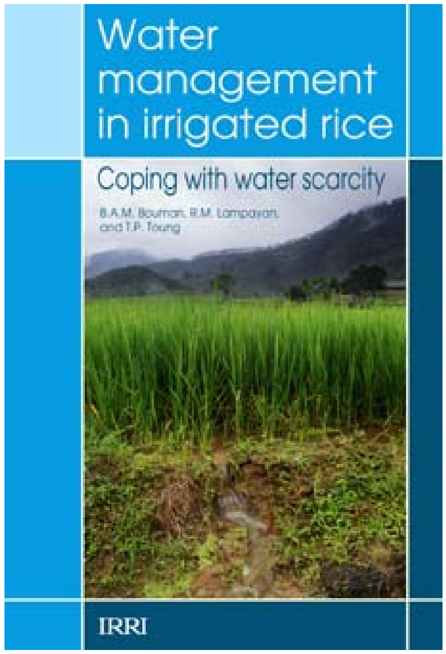
"To me, this is the best way to reach a consensus on rice research in Africa," said Dr. Seck. "However, this does not mean that excellent research is enough to change Africa's rice sector," he cautioned, emphasizing that research can have high impact only if the African countries have adequate infrastructure and a suitable environment in addition to appropriate technologies.

The joint declaration on SARC was made on the basis of the recommendations of the WARDA-IRRI-CIAT Programmatic Alignment Planning Meeting, held in June 2007 at WARDA. At the meeting, CGIAR Director Ren Wang (formerly IRRI's deputy director general for research) hailed the joint initiative as a mark of "concrete progress of the CGIAR centers in moving toward more integration and synergy."

Water management in irrigated rice: coping with water scarcity (by B.A.M. Bouman, R.M. Lampayan, and T.P. Tuong; 54 pages; developed countries US$6, developing countries $2; Philippines 100 pesos).

Worldwide, about 79 million ha of irrigated lowlands provide 75% of the total rice production. Lowland rice is traditionally grown in bunded fields that are continuously flooded from crop establishment to close to harvest. It is estimated that irrigated lowland rice receives some 34–43% of the total world's irrigation water, or 24–30% of the total world's freshwater withdrawals. With increasing water scarcity, the sustainability, food production, and ecosystem services of rice fields are threatened. Therefore, there is a need to develop and disseminate water management practices that can help farmers to cope with water scarcity in irrigated environments.

This book provides an overview of technical response options to water scarcity. It focuses on what



individual farmers can do at the field level, with a brief discussion on response options at the irrigation system level. The manual is intended as a support document for training on water management in rice production. It combines scientific background information—including many literature references for further reading—with practical suggestions for implementation.

Introductory chapters analyze the water use and water balance of rice fields, and water movement in the plant-soil system, and discuss the concepts of water scarcity and water savings. Consequences of water scarcity for sustainability, environmental impacts, and ecosystem services of irrigated rice fields are discussed later. An appendix introduces two simple instruments to characterize the water status of rice fields that can help farmers in applying water-saving technologies.

The target audience includes people involved in agricultural extension or training who have an advanced education in agriculture or water management, and who wish to introduce sound water management practices to rice farmers. For example, the book offers useful information to staff of agricultural colleges and universities, scientists, irrigation operators, and extension officers.

RECIPE

Sticky rice, prawn, and water chestnut dumplings

ARIEL JAVELLANA

Source: *Gourmet Traveller,* modified by Melissa Fitzgerald, head of IRRI's Grain Quality, Nutrition, and Postharvest Center.

Makes about 20 dumplings

Ingredients

250 g white glutinous rice, soaked in cold water for 4 hours
300 g medium green prawns, peeled and cleaned
200 g pork mince
220 g can water chestnuts, drained
3 cm piece ginger, peeled and chopped
½ cup coriander (cilantro) leaves
4 spring onions, chopped
2 teaspoons kecap manis (a sweetened Indonesian soy sauce)
1 pinch each of ground cloves and cinnamon
1 tablespoon rice flour combined with 1½ tablespoons water
1 small egg, lightly beaten
Sweet chili sauce or plum sauce to serve

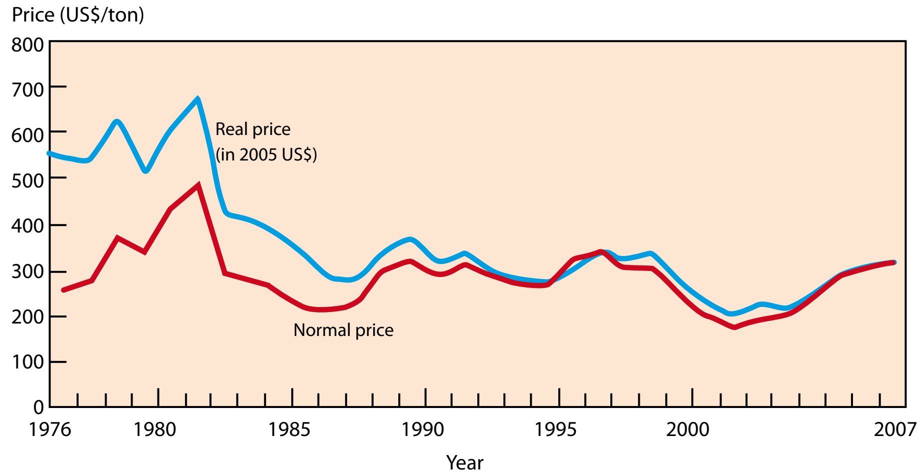
Preparation

Drain rice, spread out on absorbent paper, and let stand for 1 hour or until dry. Meanwhile, coarsely chop prawns with a knife or in a food processor, then transfer them to a large bowl, add pork, and combine well. Using a mortar and pestle or food processor, make a coarse paste from the water chestnuts, ginger, coriander, and green onions. Transfer this paste to the prawn and pork mixture, add chilies, kecap manis, spices, and 1 teaspoon salt, and stir until well combined. Next, add rice flour mixture and egg to bind. Cover and refrigerate for 1 hour.

After refrigeration, use damp hands to roll prawn and pork mixture into 20 balls of 2 cm diameter, then roll each ball in glutinous rice to coat. Transfer dumplings to large baking paper-lined bamboo steamers and steam over boiling water for 15 minutes or until rice is tender, then serve immediately with sweet chili sauce.

Where now for the global rice market?

by Mahabub Hossain
Executive director, Bangladesh Rural Advancement Committee



Trend in nominal and real prices (adjusted for inflation) of rice in the world market, 1976-2007. Source: www.WorldBank.org.

What do the coming years hold for the world's most important grain?

Several factors are combining to slow the growth in demand for rice. Rapid urbanization and increases in per capita income, particularly in the middle- and high-income countries of Asia and Latin America, are prompting people to diversify their diets, and successful population control has reduced population growth rates in countries such as China, Thailand, and Malaysia.

Although growth in demand for rice is likely to continue to decline, it may be offset by increased rice consumption due to poverty reduction among low-income households. Growth in production may also slow because of the growing scarcity of land, labor, and water. Assuming annual population growth of 1–1.5% per year, demand for rice in Asia may increase a total 10–15% over the next decade. In addition, demand for rice could increase at 3–4% per year in regions outside Asia.

An important implication of growing urbanization is that some fertile rice lands must be diverted to meet the demand for housing, factories, and roads. Also, as food habits change, markets for vegetables, fruits, and livestock products will grow stronger. Thus, there will be economic pressure to reduce the area under rice cultivation to accommodate agricultural diversification in favor of higher-value crops. Further, Asia's expansion of the nonfarm sector and subsequent increased rural-urban migration are leading to rural labor shortages and higher rural labor wage rates, further discouraging labor-intensive rice farming.

The major increase in demand for rice will come from countries in West Asia, sub-Saharan Africa, and South America. In many countries in these regions, per capita consumption has been increasing rapidly with rural-urban migration that leads to a change in food habit from diets based on maize or root crops to rice-based diets. Also, the population continues to grow quickly, particularly in Africa.

The international trade in rice has remained limited. About 7% of the world's rice production is traded internationally, in contrast to nearly 18% for wheat and 12% for coarse grains. The global rice market has expanded rapidly, however, over the past three decades. Average yearly imports of rice increased from 8.0 million tons (4.0% of production) in 1968-70 to 27 million tons in 2004-06.

After adjusting for inflation, the real price of rice in the world market in 2006 was about 25% lower than in 1985 (see figure). The long-term decline in the real price of rice has contributed to the achievement of food security, particularly in low-income, food-deficit countries in South and Southeast Asia, where many households spend over half their income on rice. The continuous decline in the real price of rice has thus helped to reduce poverty in Asia.

Two contrasting developments may substantially affect the rice economy in the future. First, as prosperous rice-growing countries move toward free trade in agricultural production, they may increasingly find it difficult to sustain producers' interest in rice farming. Economic pressure is likely to move land, water, and labor away from rice to other activities. Second, the potential for increased productivity for the irrigated ecosystem, created by the dramatic genetic enhancement of seeds in the 1960s, has almost been exploited.

The rainfed ecosystem, which accounts for about 45% of global rice area, will have to bear the major burden of a future increase in rice production. The potential for increasing yield in the rainfed ecosystem is vast, as yield is now only 1.5–2.5 tons per hectare.

Adequate investment for development, validation, and dissemination of appropriate technologies, particularly for rainfed ecosystems, will be needed to support farmers' efforts to increase rice supplies to match the growing demand emanating mostly from the increase in population in low-income countries.

Challenges for rice production in China

BY SHAOBING PENG

Rice is the staple food for around two-thirds of the Chinese people. China ranks first in annual total rice production (about 185 million tons) and second, after India, in annual total planting area (29 million hectares). The country produces 35% of the world's rice with 20% of the planting area.

Rice production in China has more than tripled in the past five decades mainly due to increased grain yield rather than increased planting area. This increase has come from the development of high-yielding varieties (including hybrid varieties) and improved crop management practices such as nitrogen fertilization and irrigation. The national average rice yield is about 6.25 tons per hectare compared with the world average of 3.75 tons per hectare.

As its population rises, China will need to produce about 20% more rice by 2030 to meet domestic needs if rice consumption per capita stays at the current level. This is not easy—several trends and problems in the Chinese rice production system constrain a sustainable increase in total rice production. These include a decline in arable land, increasing water scarcity, climate change, labor shortages, and increasing consumer demand for high-quality rice (often from low-yielding varieties).

> Several problems constrain a sustainable increase in Chinese rice production

The major problems confronting rice production in China are as follows:

Narrow genetic background. Low genetic diversity in commercially grown rice cultivars has led to vulnerability to biotic stresses (pests and diseases) and abiotic stresses (such as drought and salinity). The situation is particularly troublesome in China because 50% of the rice-planting area is occupied by hybrid rice, which is developed using only a few varieties as the female parent.

Overfertilization. In 2002, the average rate of nitrogen (N) fertilizer application for rice production in China was 180 kilograms per hectare, about 75% higher than the world average. Only 20–30% of this N is taken up by the rice plant, with a large proportion lost to the environment. In some cases, overapplication of N fertilizer may actually decrease grain yield by increasing the plant's susceptibility to lodging (falling over) and damage from pests and diseases.

Overuse of pesticides. On average, Chinese rice farmers—who tend to grossly overestimate crop losses caused by pests—are overusing pesticides by more than 40%. In many cases, overuse of pesticides actually contributes to pest outbreaks because it reduces the biodiversity of rice ecosystems, killing natural predators of pests as well as the pests themselves.

Breakdown of irrigation infrastructure. China's irrigation infrastructure was established mainly in the 1970s. Since then, maintenance of existing irrigation systems and building of new facilities have been very limited. Coupled with declining freshwater resources, this problem may greatly reduce the area planted to flood-irrigated rice in China.

Oversimplified crop management. Because of labor migration and increases in labor wages, decreased labor input for rice production has resulted in compromised crop management that may contribute to reduced yields.

Weak extension system. Because of insufficient financial support, many extension workers earn part of their salary by selling agrochemicals to farmers, which may promote overuse of fertilizers and pesticides. Furthermore, the weakness of the system means that improved technologies may not reach farmers.

Despite the challenges, good research strategies can drive increased rice production in China. These include

Increasing yield potential. China has been at the forefront in attempting to develop high-yielding semidwarf, hybrid, and new plant type varieties. Further progress in increasing rice yield potential is possible when new breeding techniques, such as marker-aided selection and genetic engineering, are combined with conventional breeding.

Drought and heat tolerance. Drought and heat stress are increasingly important constraints to rice production in China, mostly due to variation in rainfall patterns from year to year, uneven distribution of rainfall in the rice-growing season, and higher temperatures resulting from climate change. Chinese scientists have identified and mapped genes for drought and heat tolerance, and are developing new varieties.

Disease and insect resistance. Huge yield losses occur because of biotic stresses every year. Chinese scientists have isolated and cloned from cultivated and wild rice species many genes that contribute to disease and insect resistance, and have transferred these into local varieties.

Integrated crop management. New crop management technologies need to be developed using whole-system approaches. Synergy among fertilizer, water, and pest management can maximize the overall efficiency of the production system. Sustainability of the rice production system can be maintained only when the natural resource base is protected and the health of the rice ecosystem is maximized.

Dr. Peng is a senior crop physiologist at IRRI.

Cuu Long Delta Rice Research Institute

30th Anniversary 1977-2007

The Cuu Long Delta Rice Research Institute (CLRRI), Vietnam's premier national rice research institute, is celebrating its 30th anniversary. Part of the Ministry of Agriculture and Rural Development, CLRRI was founded in 1977 by the then Prime Minister Pham Van Dong. The institute began its life as the Cuu Long Delta Agricultural Technology Center and, in 1985, was upgraded and took its present name.

CLRRI's Mission

- Establish and implement short- and long-term research and technology transfer plans according to the overarching socioeconomic development plans of the government.
- Carry out research on rice and other major crops in the Mekong Delta. The main research themes are

  Genetics and plant breeding of rice and rice-based crops such as soybean, maize, and mungbean;

  Rice seed multiplication of leading varieties (breeders' seed, foundation and certified seed);

  Field inspection, seed testing, and issues of seed certification of rice varieties;

  Agricultural mechanization, postharvest processing, and storage;

  Proper use and management of agro-chemicals and natural resources, and protection of the agroecological environment;

  Using biodiversity for sustainable management of rice pests and diseases; and

  Agricultural systems development, socioeconomic and rural development.
- Provide opportunities for postgraduate study and dissertation, and training in electro-mechanic and agricultural technologies.
- Collaborate with other Vietnamese and international organizations toward the sustainable agricultural and rural development of the Mekong Delta.

CLRRI's achievements are many and varied. CLRRI rice varieties occupy more than 70% of the Mekong Delta region's rice-growing areas, and more than 70 CLRRI-developed varieties have been released for production in the Mekong Delta and beyond. Over 2,000 cultivated rice samples and hundreds of specimens of wild rice species have been collected and conserved in CLRRI's genebank, many of which have been used in CLRRI breeding programs.

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