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Rice Today

International Rice Research Institute
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Dawn of a new era in rice improvement

A never-ending season in the Philippines

Flying heroes of Ecuador's rice fields

A game changer in Africa's rice agronomy

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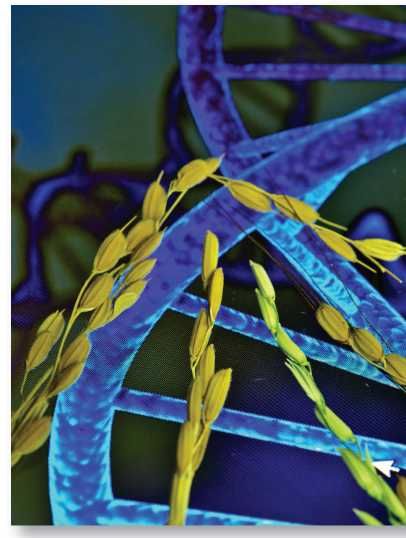
contents



ISAGANI SERRANO

About the cover. Rice genomes with their genes and DNA sequences. On 28 May 2014 (World Hunger Day), IRRI and its partners announced the completion of the sequencing of 3,000 rice genomes, which has been called an unparalleled development in plant science. Most significantly, the project's entire 13.4-terabyte dataset has been released—with no strings attached—to the world's rice researchers. Read the cover story beginning on page 24. Cover concept: Isagani Serrano.

Rice Today is published by the International Rice Research Institute (IRRI) on behalf of the Global Rice Science Partnership (GRiSP).

IRRI is the world's leading international rice research and training center. Based in the Philippines and with offices located in major rice-growing 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. It is one of the 15 nonprofit international research centers that are members of the CGIAR consortium (www.cgiar.org).

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Partnerships that work

Rice Today has come a long way since its first issue in 2002, when its editorial contents were almost all coming from the International Rice Research Institute (IRRI). The magazine has evolved along with rice science. It now works as part of the new world of rice research under the Global Rice Science Partnership (GRiSP), a global initiative to bring together more than 900 institutions in solving the challenges in rice production.

Partnership, collaboration, and working together became the operational words of GRiSP's work in its goals of increasing rice productivity and value for the poor, fostering more sustainable rice-based production systems, and improving the efficiency and equity of the rice sector through better and more accessible information, improved agricultural development and research policies, and strengthening delivery mechanisms.

Like GRiSP, the contents of the magazine also point in this direction for, truly, no one is an island in the world of rice science and development.

For example, success in the unprecedented sequencing of 3,000 rice genomes of varieties and lines is a product of collaboration among IRRI, BGI in Shenzhen, China, and the Chinese Academy of Agricultural Sciences. See *Dawn of the new era in rice improvement* on pages 24-27 to find out how this achievement is changing the way rice breeding is done.

In IRRI's Long-Term Continuous Cropping Experiment, people working together spans several generations of scientists who have worked to answer some questions that are critical for the future of rice farming. Is intensive farming sustainable? How much rice can a farmer optimally produce on a piece of land in a year? Can farmers produce more with less use of resources such as water, land, and farm inputs and with less impact on the environment? Find the answers to these questions on pages 10-15.

In India, we highlight a knowledge dissemination effort that complements the work of the Stress-Tolerant Rice for Africa and South Asia (STRASA) project that is providing farmers with improved management practices to successfully grow the new climate-smart rice varieties. See *More than seeds* on pages 36-37.

On to Latin America where seven countries are working together with the International Center for Tropical Agriculture (CIAT) to push the rice breeding envelope to improve the lot of rice-growing communities in the region (pages 30-31). And, in Ecuador, farmers may find that allying with birds of prey could help them combat apple snails, a serious rice pest (see *Flying heroes of Ecuador's rice fields* on pages 28-29).

From Africa, read about Kazuki Saito—one of the continent's "most valuable players" in rice research. On pages 34-35, see how his determination and leadership in conducting field research, in close collaboration with researchers and farmers, are leading to tangible results, even under difficult circumstances.

We also have a story that might rekindle your belief in love and destiny. IRRI's Krishna Jagadish and Impa Somayanda found one another through science—and love has kept them together ever since in *Smitten by Science* (page 32).

We have a double dose of rice facts in this issue. David Dawe, FAO senior economist, explains why rice is cheaper on the world market but more expensive in some local markets and why, in some countries, this is not the case (see *The two faces of rice prices*, on pages 40-41). And Sam Mohanty, IRRI's senior economist, sheds light (pages 38-39) on why *The global rice market is winking at* El Niño *and Thai problems*.

In our *Grain of Truth* column on page 42, Tony Fischer, a renowned agricultural scientist from Australia, provides some insights into *Yield increase prospects for rice to 2050* and gives some clues on how we could close the gap between the demand for rice in 2050 and the supply.

I hope you enjoy these and our other features in this issue.

Lanie Reyes
Rice Today managing editor

Are resilient traits in African rice key to self-sufficiency?


R RAMAN, AFRICARICE

Africa Rice Center (AfricaRice) launched a 5-year project that will work to isolate high-value genes in African rice (*Oryza glaberrima*) that can cope with drought, flood, and soil-related constraints. The first step in the project will be to identify genes and gene-based markers that are related to iron tolerance, drought tolerance, and anaerobic germination ability (tolerance of flooding during germination). The desirable genes will then be incorporated into rice varieties with other characteristics farmers prefer and that make these varieties commercially valuable.

AfricaRice is partnering with the National Institute of Agrobiological Sciences in Japan, Cornell University in the U.S., the International Rice Research Institute, and the National Cereals Research Institute in Nigeria for this project.

Source: http://oryza.com

AfricaRice to boost rice R&D capacity in Eastern and Central Africa


R RAMAN, AFRICARICE

The Africa Rice Center (AfricaRice) Board of Trustees has approved the Center's Development Plan for 2014-20, which proposes a stronger presence of the Center in Eastern and Central Africa to enhance rice research and development capacity in the two subregions.

The Center's Development Plan is expected to improve operational efficiency and develop greater cohesion of AfricaRice's activities, most of which will continue to be conducted under the umbrella of the CGIAR Research Program on Rice, led globally by the International Rice Research Institute, with AfricaRice leading the activities in Africa.

Source: www.seedquest.com

Rice sector developments in selected West African countries

R RAMAN, AFRICARICE

The U.S. Department of Agriculture (USDA) has posted a review of rice production trends in 11 West African countries (excluding Nigeria), with a focus on Burkina Faso, Côte d'Ivoire, Mali, and Senegal. Between 2012 and 2015, overall rice production in the selected countries is projected to increase by 40%, in the context of a 20% rise in consumption. This is projected to lead to an 18.5% decline in imports between 2012 and 2015, according to USDA estimates.

The countries where rice production is projected to grow between 2012 and 2015 are Côte d'Ivoire (+154%), Burkina Faso (+40%), Chad (+27%), Senegal (+26.8%), Guinea Bissau (+23.8%), and Mali (+19.5%).

The strong growth in rice production in Côte d'Ivoire will make it the biggest rice producer by 2015 of the countries reviewed. This follows the implementation of a revised National Rice Strategy, which seeks to reach production of 2 million tons of milled rice by 2020.

Source: http://agritrade.cta.int

Stay connected with AfricaRice wherever you are

AfricaRice has introduced its new mobile website for any mobile device user with Internet connectivity. The new mobile-friendly website will provide smartphone users with easier access to current updates and the latest information on jobs, news, publications, videos, photos, and podcasts. Visit www.africarice.org/mobile on your mobile device now!

Sustained food security depends on improving the lives of farmers

The plight of farmsteads and farm labor and how this will affect efforts to secure the world's food supply were key issues discussed during the World Economic Forum on East Asia held recently in the Philippines.

Robert Zeigler, director general of the International Rice Research Institute (IRRI), called on governments and the private sector to join hands to ensure that farming families share in the benefits of inclusive growth. Dr. Zeigler helped focus discussions on food security and agriculture on farmers and how they can be supported better to produce the world's food, amid increasing incentives to leave farming—not least of all losses and uncertainties posed by the changing climate.

"Climate change hastens the deterioration of rice-growing areas and the condition of the poorest farmers, who already till unfavorable land to begin with," he said. "This also means that, with each successful targeted intervention, the poorest of the world's farmers stand to benefit the most."

IRRI has a whole arsenal of rice production knowledge and interventions sharpened by more than five decades of research that includes climate-smart rice varieties, good crop management practices for specific conditions, postharvest practices that reduce losses from nonoptimal storage, and many others shared with stakeholders across the rice value chain. Dr. Zeigler said that the benefits of interventions for farmers across Asia and Africa are being further enhanced with the use of communication technology and satellite imagery. He added that rice farmers will benefit from better access to information that will help them make better decisions on the farm, which will, in turn, make them "better credit risks."

New irrigation technique can ease drought effect on rice


DONNA CASIMERO, IRRI

A simple irrigation technique developed by the International Rice Research Institute called alternate wetting and drying (AWD) can cut down water use by as much as 25% in producing rice. It typically takes 2,000 liters of water to produce a kilogram of paddy. AWD can save up to 500 liters of water per kilogram of rice. Departing from the conventional way of growing rice that uses continuous flooding, AWD makes use of the cycle of draining and re-flooding of rice paddies, keeping an optimum water level at any particular time.

AWD is now being introduced to farmers across Asia. IRRI and its partners have high hopes for the technology. In Vietnam, farmers have credited AWD for yield increases. Decreased water use also reduced the occurrence of lodging (when rice plants keel over because of heavy rain) and helped the plants grow better tillers and stronger roots. The resulting improved field conditions help reduce labor cost at harvest, as mechanical harvesting becomes feasible.

AWD also helps decrease greenhouse gas (GHG) emissions, specifically methane, by up to 50%. Methane emissions are caused by flooding of rice fields. Intensive research by scientists from IRRI and its partners has helped AWD evolve into one of the most mature GHG mitigation methods in the agricultural sector. AWD could thus become a key component for GHG mitigation in many Asian countries.

Climate-smart rice now grown by 10 million farmers

About 10 million of the poorest and most disadvantaged rice farmers have been given access to climate-smart rice varieties, which include the flood-tolerant Swarna-Sub1 developed by the International Rice Research Institute (IRRI).

"Swarna-Sub1 changed my life," said Mr. Trilochan Parida, a farmer in Odisha, India. Floods ravage Trilochan's rice field every year. Flooding of four days or more usually means a painful loss of the crop as well as of any expected income. In 2008, however, an amazing thing happened: Trilochan saw his rice rise back to life after having been submerged for two weeks. Trilochan is one of millions of farmers who have found that a solution exists to flooding problems in rice fields. They are no longer at the mercy of the seasons, which they have been for generations.

Climate-smart rice varieties are made to especially thrive in environments affected by flooding, drought, cold temperatures, and soils that are too salty or contain too much iron, which leads to iron toxicity. IRRI collaborates with more than 550 partners in delivering climate-smart rice varieties to farmers in South Asia and Africa. These partners include national agricultural research and extension systems, government agencies, nongovernment organizations, and private sector actors, including seed producers.

Fighting deadly disease with grains of rice

Researchers at the University of Tokyo are bioengineering rice in a bid to turn it into an easy and low-cost storage and delivery medium for drugs to combat common infectious and contagious illnesses.

The immediate target is to develop new treatments against cholera and rotavirus, two causes of severe and often fatal diarrhea. Cholera now kills as many as 120,000 people a year, according to the World Health Organization, while rotavirus is estimated to kill about 500,000 children a year under age 5, amounting to about 5% of all child deaths worldwide.

Source: http://www.nytimes.com

Italy begins drive to save historical rice varieties

Italy is conserving thousands of historical rice varieties by continuing to grow them to avoid degeneration. Historical rice varieties such as Maratelli one, Vialone Nero, Bertone, and Chinese Originario existed some one-and-a-half centuries earlier and are considered to be the origin for many of the latest rice varieties now grown in Italy.

Source: http://oryza.com

RiceToday around the world

▲ **FRENCH RICE.** ***Rice Today*** **makes a guest appearance at the CGIAR Communication Leaders Community of Practice Annual Meeting 2014 held at the CGIAR Consortium headquarters in Montpellier, France. One of the aims of the annual meeting is to strengthen and make better use of the latest communication tools.**

◀ **GENE HETTEL, editor-in-chief of** ***Rice Today*** **magazine, near Baidyabati Village, West Bengal, India, with farmers who are telling him about their excellent experiences growing the flood-tolerant rice variety Swarna-Sub1.**

Crop yields and global food security—will yield increase continue to feed the world?

By T. Fischer, D. Byerlee, and G. Edmeades

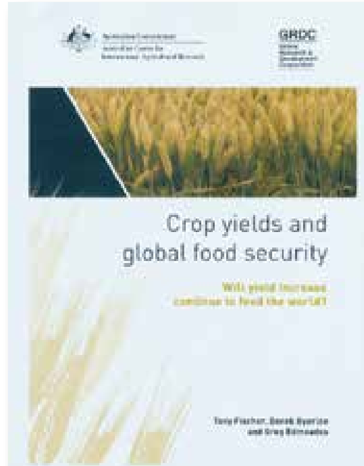
Published by the Australian Centre for International Agricultural Research (ACIAR). 640 pages.

This book, by world-renowned agricultural scientists—Tony Fischer, Derek Byerlee, and Greg Edmeades—is an invaluable reference on the opportunities for crop yield increase to feed the world to 2050. It covers the supply side of the world food situation and considers the major influences on yield.

More than 20 crops are considered but particular attention is given to the four major staples: rice (see *Grain of truth* on page 42), wheat, maize, and soybean. A broad view is taken, ranging from breeding of the crop to its socioeconomics, along with implications for resource use efficiency and the environment.

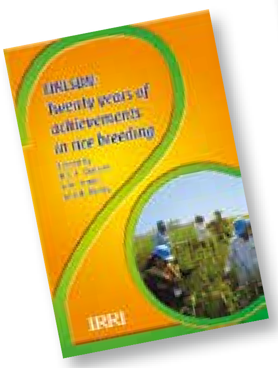
Aimed at agricultural scientists and economists, decision makers in the food production industry, concerned citizens, and tertiary students, the book provides:

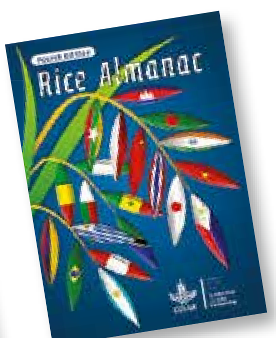
- a detailed tour of the world's key breadbasket regions to understand progress in crop yields over the past 20 years,
- a discussion of ways for achieving the target yield goals for food security without substantially increasing cultivated lands, and
- implications of further yield increase for resource use, agricultural sustainability, and the environment.

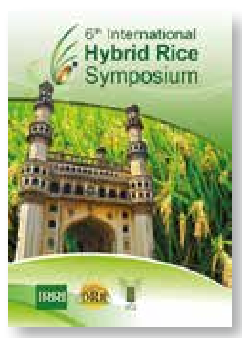


Topics include molecular biology, crop physiology, crop agronomy, private plant breeding, genetic engineering, conservation agriculture, herbicide resistance, organic farming, agricultural extension, resource productivity, policy, trade, farm ownership, environmental degradation, and climate change.

Free download of the publication (PDF) is available on the ACIAR Web site at http://aciar.gov.au/publication/mn158. Printed copies of the book can be purchased via the Web site as well. To arrange for bulk order discounts or sale on consignment, contact ACIAR Communications at aciar@aciar.gov.au; phone: +61-2-621-70534.







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TRAINING COURSES AT IRRI

Course title	Date	Venue
Rice Production Techniques for Research Technicians (*targeted for African participants*)	28 July-15 August 15	IRRI, Philippines
Research Data Management	26-28 August	IRRI, Philippines
Molecular Breeding Course	22 September-3 October	IRRI, Philippines
Rice: Postproduction to Market (*Second offering*)	13-24 October	IRRI, Philippines
Research Data Management	21-23 October	IRRI, Philippines
Basics of Rice Production (*Second offering*)	28-30 October	IRRI, Philippines
Basic Scientific Writing Course	10-14 November	IRRI, Philippines

For inquiries, contact IRRITraining@irri.org, m.maghuyop@irri.org, or a.aquino@irri.org. Phone: (63-2) 580-5600 ext 2538 or +639178639317; fax: (63-2) 580-5699, 891-1292, or 845-0606; mailing address: The IRRI Training Center, DAPO Box 7777, Metro Manila, Philippines (Attention: TC Course Coordinator); Web site: www.training.irri.org.
Note: Fees and schedules are subject to change without prior notice.

A NEVER-ENDING SEASON

by **Alaric Francis Santiaguel**

An experiment that has been going on for more than half a century could hold a solution to a nagging concern of feeding an ever-increasing population with shrinking resources

ISAGANI SERRANO (5)

You wouldn't know it by simply looking at it, but a one-hectare rice field at the International Rice Research Institute (IRRI) in the Philippines has been in perpetual motion since 1962. The Long-Term Continuous Cropping Experiment (LTCCE) recently marked its 150th rice cropping season, making it one of the longest running agricultural experiments in the world, and the most exciting.

The LTCCE, however, wasn't conceived to make it into the Guinness Book of World Records. It measures trends in yield and soil properties over its lifetime as indicators of the sustainability of continuous rice cropping on flooded soil. The data being collected from the LTCCE might not directly resonate with the public, but this experiment could actually answer perhaps the most important question of our time: how shall we produce enough rice for a growing population in a sustainable way?

The ghost of Malthus

In *An Essay on the Principle of Population* (1798), Thomas Malthus predicted that an outbreak of famine and diseases was inevitable and it was only a matter of time. About 150 years later, the world found itself teetering dangerously on the brink of a global famine as food production lagged behind population growth. But, a timely intervention between the 1940s and the late 1960s, known as the Green Revolution, increased agricultural production worldwide and is credited with saving more than a billion people from starvation.

But the Green Revolution did not permanently lay to rest the specter of a Malthusian catastrophe. Norman Borlaug, the father of the Green Revolution, had no illusions that it was anything other than a means to buy the world time, according to Robert Zeigler, IRRI director general.

The world doesn't have much time when it comes to food production. More than 7 billion people are now living on a planet with finite resources. Arable land covers only 3% of the world's surface and this is continually being converted into urban area. One hectare of productive land is estimated to be lost every 7.67 seconds. With current global trends in diets and population, 60% more food will be needed in 2050. One way to meet this demand is by putting food production on overdrive through intensive agriculture.

Squeezing rice from land

Intensive agriculture is an approach designed to obtain the most yield by using techniques such as planting more or different crops on a unit of land and increasing the frequency of cropping per year. Experts say intensive farming is not new. It has been practiced for thousands of years in Egypt, South Asia, Europe, and North and South America. In many Asian countries, intensive rice farming was practiced by carving terraces on hilly and mountainous areas to make them suitable for growing a crop.

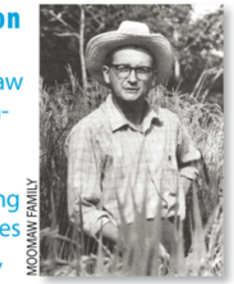
Today, intensive agriculture is often equated with modern commercial agriculture—mechanized farming, large-scale plantations, and raising livestock in confined spaces—that started after the end of World War II. Prior to that, agricultural systems relied mostly on growing traditional varieties, organic matter, biological control of pests and diseases (through crop diversification and rotation), and natural rainfall patterns. These types of farming systems were closely linked with the natural systems and caused little environmental degradation.[1] Although food production this way made outputs stable, the quantity was modest.

On the other hand, modern commercial agriculture used modern varieties, inorganic fertilizer, pesticides, and irrigation, which allowed many developing countries to achieve dramatic increases in farm production. But, these practices came under heavy fire for being unsustainable and environmentally destructive. Criticisms included a reduction in soil fertility because of the heavy use of inorganic fertilizers, narrowing of genetic diversity as more farmers shifted to modern high-yielding crop varieties, more frequent outbreaks of pests and diseases, and increased soil erosion. Just how far can we push this without causing system failure?

A brave new farm

In 1962, the LTCCE (then called the Maximum Yield Experiment) was created with James Moomaw as its first head scientist (see box). It aimed to sustain high annual rice yield from a unit area of land using an optimum mix of rice varieties and cultural practices.

One man's vision



MOOMAW FAMILY

James Moomaw was an agronomist at the University of Hawaii specializing in tropical pastures and forage crops, and had never grown a rice crop. However, Robert Chandler, IRRI's first director general, knew he was the right man to become the Institute's first agronomist, in 1961. The North Dakota native specialized in soil fertility and developed a first-class research program at IRRI for investigating continuous rice cropping management practices involving fertilizer response, water management, and weed control.

His expansive knowledge was matched by his passion to search for solutions to poverty and hunger. Dr. Moomaw believed that knowledge holds the answers. He proved this with the LTCCE, which he pioneered, by producing 18.8 tons per hectare of rice from 3 crops in a year, in 1966—the first rice scientist to do so—using improved rice cropping technology.

He knew that global hunger was a constant threat. "If your technology fails for whatever reason at just one time, you have a disaster on your hands," he once said. Fifty-two years later, the LTCCE, in line with Dr. Moomaw's conviction and vision, continues to update and validate rice production practices for a changing climate and in keeping the threat of global hunger at bay. He passed away prematurely at age 55 in 1983.

"IRRI scientists already had foresight of envisioning continuous rice cropping with as many as three crops of rice per year," said Roland Buresh, IRRI soil scientist and current lead researcher for the LTCCE. "They were seeing already at that time that the key ingredients would entail varieties, irrigation water, proper timing and use of fertilizer, and the use of good agricultural management practices."

[1] Altieri MA. 1995. Agroecology: the science of sustainable agriculture. Westview Press, Boulder.

In March of 1966, IR8, developed by IRRI, was included in the experiment. IR8, also known as "miracle rice," could yield up to 8.7 tons per hectare in high-yielding seasons. Succeeding IRRI varieties were used later. The IRRI varieties were not only heavy grain producers. They also matured earlier and could be harvested in about 115 days. This enabled Dr. Moomaw to pioneer three cropping seasons in a year, a feat not possible with longer-duration traditional varieties.

"The introduction of IR8 was really a game changer in intensive rice production," said Dr. Buresh. "The key varieties for attaining high yield are usually the recently introduced varieties that are early-maturing and resistant to pests and diseases."

A 52-year history of sustainability

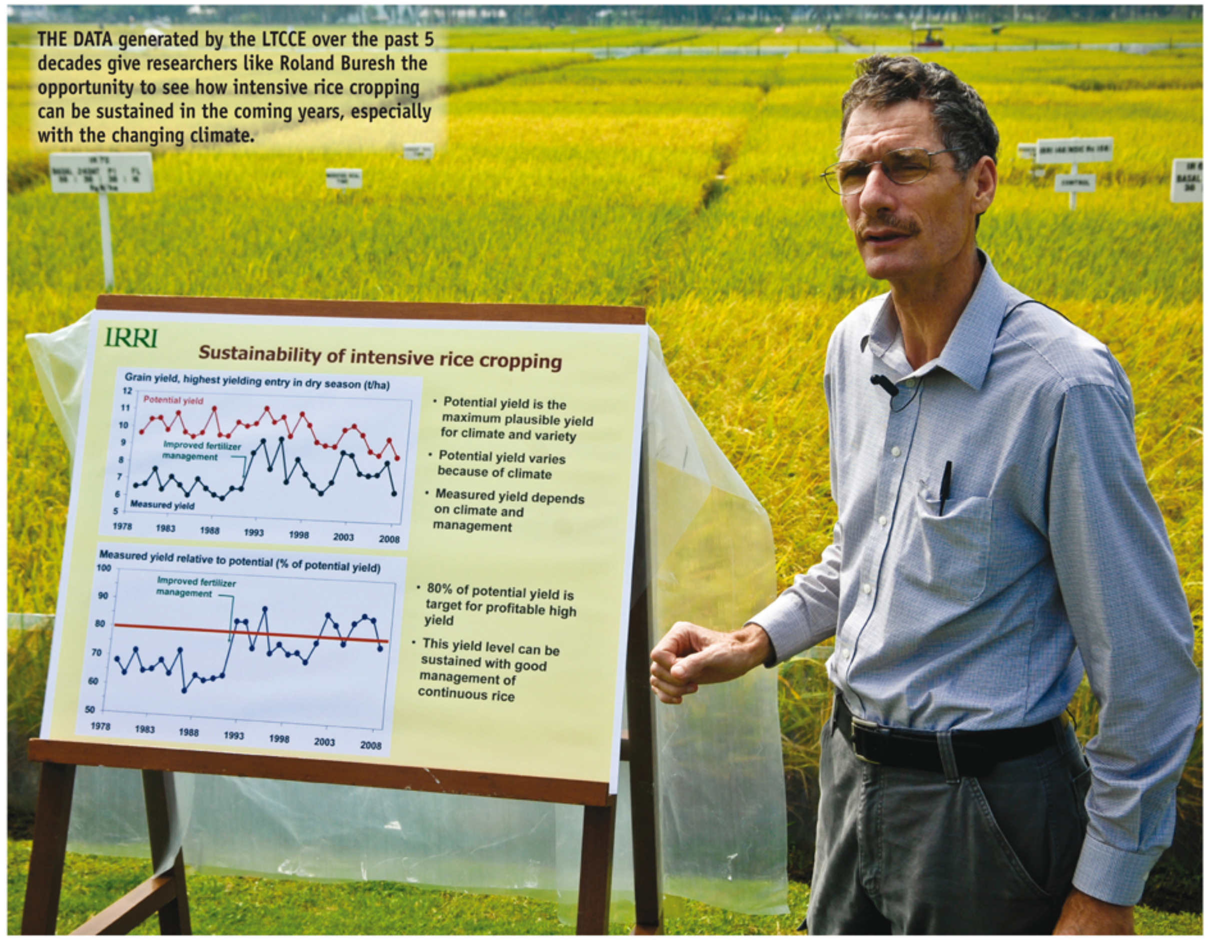
"What we have here are records through time and the opportunities to really see how to sustain this system in the changing climate," said Dr. Buresh at the ceremonial harvesting of the LTCCE's 150th crop in April 2014. "We have before us not only the 52 years of history of sustainability but a benchmark on sustainability into the future."

In fact, the soil organic matter content in the field did not decrease from 1983 to 2009 even though most remaining crop residues after each harvest were removed and not incorporated back into the soil. The continual balanced application of manufactured fertilizer did not adversely affect soil health.

Living proof

From the point of view of soil scientists, sustainability is the ability of the soil to maintain its organic matter content and fertility over time.

"The LTTCE is a research environment for us to look at traditional rice production, in which rice is cultivated under flooded conditions," said Dr. Buresh. "This creates a very favorable environment for rice crops to be grown. It helps control weeds, increases the availability of nutrients, and creates a soft layer for easy transplanting of rice. These have contributed in part to the sustainability of this system."



THE DATA generated by the LTCCE over the past 5 decades give researchers like Roland Buresh the opportunity to see how intensive rice cropping can be sustained in the coming years, especially with the changing climate.

The sustainability of rice cultivation in the LTCCE can be assessed by comparing actual yields with the maximum potential yield of a variety. Scientists estimate this potential yield with a crop simulation model and weather data for each season. And, yield in the LTCCE since 1992 has remained near 80% of potential yield, which represents a target for achieving the highest profit with good crop and fertilizer management.

An imperfect perfect system

Although the LTCCE may have found the secret to maintaining soil fertility even under constant cropping, it has also revealed the chinks in the system.

Despite the steady soil fertility and good agricultural management, the LTCCE team observed that yields declined in the 1970s and 1980s. The culprit was inefficient application of nitrogen fertilizer. From 1992 onward, however, yields increased when nitrogen fertilizer application was improved and efficiently distributed at critical crop growth stages of the plant.

"This system requires a great deal of water and energy," Dr. Buresh said. "It takes a lot of labor and mechanical equipment."

But these agricultural inputs are expensive for smallholder farmers. They usually have no choice but to borrow money at very high interest rates, leaving them heavily in debt. The labor shortage as a result of migration from rural to urban areas is also becoming a major problem.

Dr. Buresh and his team are therefore exploring other cultural management practices that more closely reflect real-world conditions. These conditions are being redefined by climate change and decreasing resources, among other factors that could undermine rice production and pose sharp risks to food security in coming decades.

Brief history of the world's longest-running rice experiment

1962


James Moomaw begins the Maximum Yield Experiment (MYE).

Beatles make their broad-casting debut on BBC radio.

1963


MYE is renamed the LTCCE.

Valentina Teresh-kova, first woman in space, returns to Earth.

1966


IR8 is planted in the LTCCE. Three cropping seasons per year become possible with modern rice varieties. LTCCE produced 18.8 tons/ha—considered a record at the time.

Mihir Sen is the first ever to swim Palk Strait between Sri Lanka and India.

1968


S.K. De Datta becomes leader of the LTCCE.

Summer Olympic Games open in Mexico City.

1969


The all-time highest yield is recorded across the 3 crops (22.7 tons/ha).

Neil Armstrong is the first human to set foot on the moon.

1986


Golden apple snail becomes a major pest of rice in the Philippines.

Experimental airplane Voyager, piloted by Dick Rutan and Jeana Yeager, completes the first nonstop, round-the-world flight without

1991


Ken Cassman becomes leader of the LTCCE.

Mt. Pinatubo in the Philippines erupts. It is the second-largest volcanic cata-clysm of the 20th century.

1993


A comple-mentary long-term experiment is started on sustainable diversification from continuous rice cropping to a rice-maize rotation.

Nelson Mandela and South Africa president F. W. de Klerk are awarded the Nobel Peace Prize.

1996


Osamu Ito becomes leader of the LTCCE.

IBM computer Deep Blue becomes the first computer to win a game of chess against a reigning champion, Gary Kasparov.

2000


Roland Buresh becomes leader of the LTCCE.

The first passenger rail link between India and Bangladesh is opened.

2008

SSSAJ
SOIL SCIENCE SOCIETY OF AMERICA JOURNAL

Study shows that over a 15-year period in the LTCCE there was no decline in soil organic matter. (Soil Sci. Soc. Am J. 72:798-807).

Barack Obama, is elected the 44th U.S. President.

2011


LTCCE serves as the benchmark of sustainable productivity for ecological intensification (EI) research initiated at IRRI.

World popu-lation reaches 7 billion.

2014

150th Crop

150th crop of the LTCCE is harvested demonstrating the sustainability of intensive rice cultivation.

International Rice Congress to be held in Bangkok, 27 October-1 November.

4TH INTERNATIONAL RICE CONGRESS

The LTCCE is dedicated to investigating the best management practices for sustainable farming—from the early days of the Green Revolution to production models using upcoming technologies.

A thirst for growth

Water is critical to future growth but the planet's fresh water can sustain only so much growth. In 2014, an unusually early dry season—and the diversion of water to the Three Gorges Dam—caused China's Poyang Lake to dry up, threatening a million people living in surrounding areas with water shortages. The costs of lost livelihood and ecological damage are staggering. What makes this truly alarming is that Lake Poyang is China's largest freshwater lake—twice the size of London! If the water sources that feed major rice production sites in Asia were to run dry, the impact would be catastrophic.

"Intensive rice cropping is possible only because we have sufficient water for irrigation," said Teodoro Correa Jr., who manages the daily operations in the LTCCE. "We cannot do this in the event of severe water scarcity in the future."

In 2012, the LTCCE adopted alternate wet and dry (AWD) irrigation. This is a water management system in which rice fields are not kept continuously submerged. Instead, it allows fields to go without irrigation from 1 to up to more than 10 days (as long as water levels do not drop below 2 cm) before flooding the fields again. This reduces water use without significantly affecting rice yield and has been successfully used in Bangladesh and Indonesia.

"We know that continuous flooding preserves the organic matter content of the soil even with intensive cropping," said Mr. Correa. "How will AWD affect soil fertility? That remains to be seen."

Adjusting the flooding patterns with one or more dry periods could maintain the overall organic matter of the soil at a fairly stable level. But it will take at least 5 years for the LTCCE to collect the necessary data to verify this.

Too hot for comfort

The LTCCE has also shown that yields since 1992 have varied from year to year. And, insect pests and diseases have not affected rice yields because the varieties grown in the LTCCE are regularly replaced with new high-yielding ones that are pest- and disease-resistant. Rice yields are higher in years and seasons with abundant sunlight, yet yields have dipped during the dry season (from January to April) when rice is supposed to produce more grains. Both Dr. Buresh and Mr. Correa are looking skyward for possible explanations.

"Rice is sensitive to sunlight," said Mr. Correa. "Rice plants yield lower during the wet season because of overcast skies. But we have noted having more cloudy days during the dry season." Climate experts believe that the increasing global temperatures will cause greater evaporation of water, mainly from oceans, into the atmosphere and this

A FIELD worker reaps part of the 150th crop of the longest-running field trial on rice in the world.

is likely to cause more clouds to form. Increased cloudiness is not a bad thing because it reduces the amount of sunlight reaching the surface of the planet, thus helping it cool down. But, for rice production, this means signs of gloomy days ahead.

Dr. Buresh added that haze in the atmosphere caused by increasing air pollution may have something to do with this as well.

How can rice farms of the near future cope with the new normal? Forthcoming research in the LTCCE could provide remedial measures.

The never-ending search for answers

In 2011, IRRI began research on ecological intensification (EI) to develop new rice production systems that can sustain high yields with more efficient use of resources such as water, labor, energy, and fertilizer. The EI project is looking at futuristic rice production models with high and stable yields, highly efficient use of resources, cropping rotations, less use of pesticides, improved or maintained soil quality, and greater adaptation to climatic fluctuations.

IRRI DIRECTOR General Robert Zeigler (*left*) and LTCCE Manager Teodoro Correa, Jr., inspect one of the varieties harvested in the 150th LTCCE.

The LTCCE now provides a benchmark for sustainable rice production against which the productivity, sustainability, and profitability of rice production systems emerging from EI research can be assessed. The best ones could be the next set of gold standards for growing rice in a world that has become quite different from just a few decades ago.

For this reason, the LTCCE is far from being irrelevant or outdated. The LTCCE has become even more important as ground zero for sustainable rice cropping management necessary to feed several billion people in the future.

"I find this experiment to be one of the most exciting places in the Institute," said Dr. Zeigler. "No other research organization can address these kinds of questions. This is something that is incredibly important."

Mr. Santiaguel is associate editor of Rice Today.

View a video of the LTCCE's ceremonial 150th harvest at: http://youtu.be/RJDFvhh1i4s.

One rice, thousand gold

retold by **Changrong Ye**
illustrated by **Hanna Joy Malabanan**

An old Chinese fable teaches people to repay the kindness they received and offer help to those who need it

A long, long time ago, during the Qin Dynasty in China, there was a boy named Hán Xìn (Han-Shin). He was born in a very poor family and often had nothing to eat. He often went down to the river to fish, but rarely caught anything, so he was always hungry.

One day, a group of women were washing clothes in the river where Hán Xìn was fishing. An old woman saw that he was very thin and looked hungry so she came over to Hán Xìn and handed him a bowl of rice.

"You look hungry, little boy," she said. "Please eat this bowl of rice."

"Thank you so much," said Hán Xìn as he bowed down to the old woman.

Since then, every time Hán Xìn encounters the old woman at the river, he never goes hungry.

Hán Xìn was very grateful to the old woman. "I will find a way to pay you back someday," he said.

"Why do you promise so much when you have nothing?" she said. "I give you rice because I feel sorry that you don't have anything to eat. I don't expect you to repay to me. If you were a real man, you would find a way to support yourself."

Hán Xìn felt ashamed. But he knew that the old woman was right, so he worked hard to seek his fortune.

When Hán Xìn grew up, he became brave and kind. He joined the rebel forces that eventually overthrew the emperor of the Qin Dynasty in 206 BC. He rose through the ranks and became an army general. In the end, he was conferred the titles of "King of Qi" in 203 BCE and "King of Chu" in the following year of the Han Dynasty. He did many good things and helped many people. He became rich and was well respected.

But, Hán Xìn never forgot the old woman who had given him rice when he was poor and hungry. He went back to the village and looked for her. At last, Hán Xìn found the old woman. He took her to his palace. Hán Xìn bowed down to the old woman and gave her a bowl filled with gold.

"I promised I would pay you back someday," he said. "Please take the gold."

The old woman was delighted with Hán Xìn's gestures, but refused to take the gold. "Thank you for the gold," she said. "But you have already paid me back by becoming a strong and kind man."

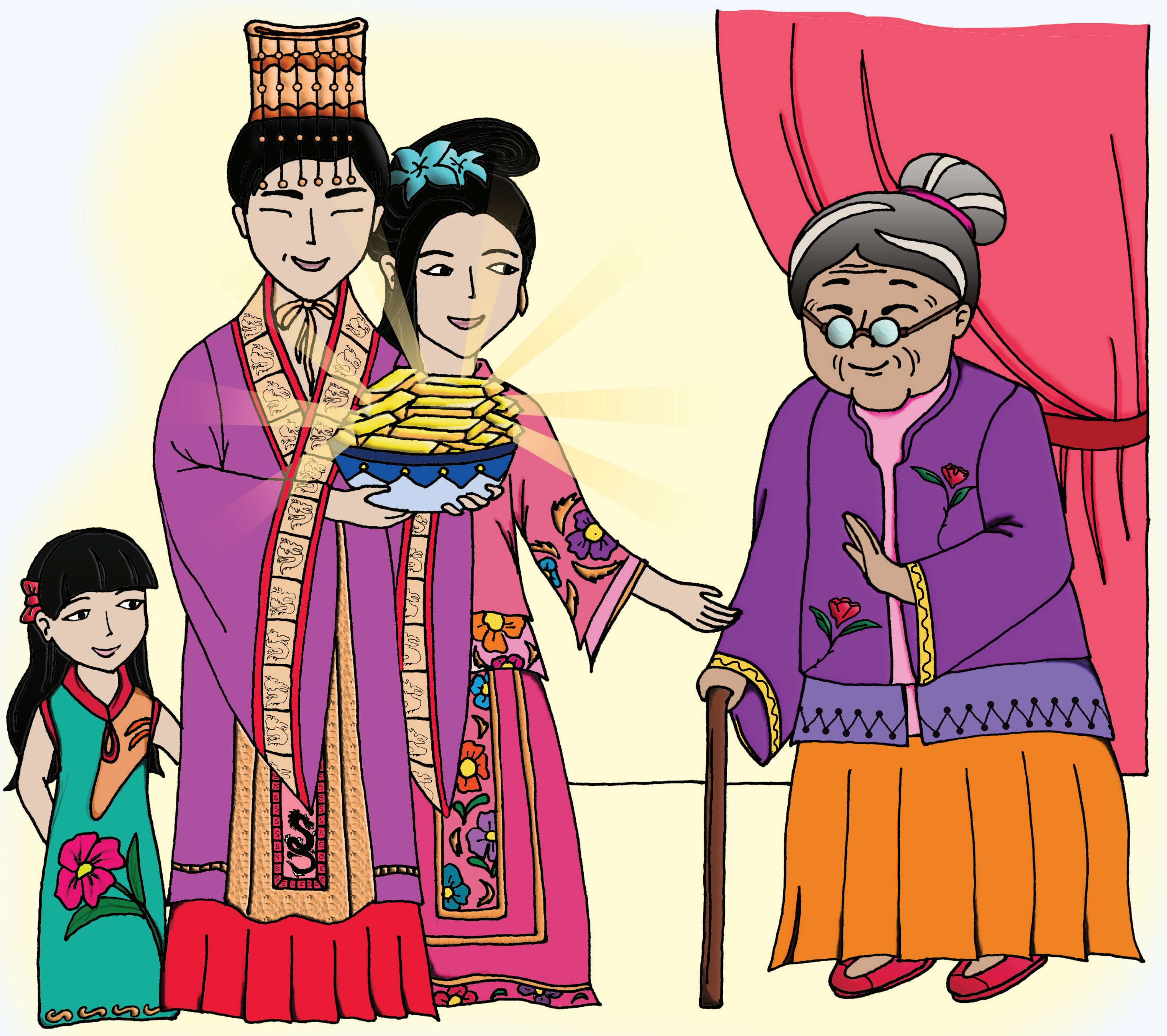
The story of Hán Xìn passed from generation to generation and it is still often used to remind us that even small acts of helpfulness are very valuable to those who really need them so we should help when we are able to do so. It also teaches us that we should not forget the kindness that people offer to us and that we must repay them.

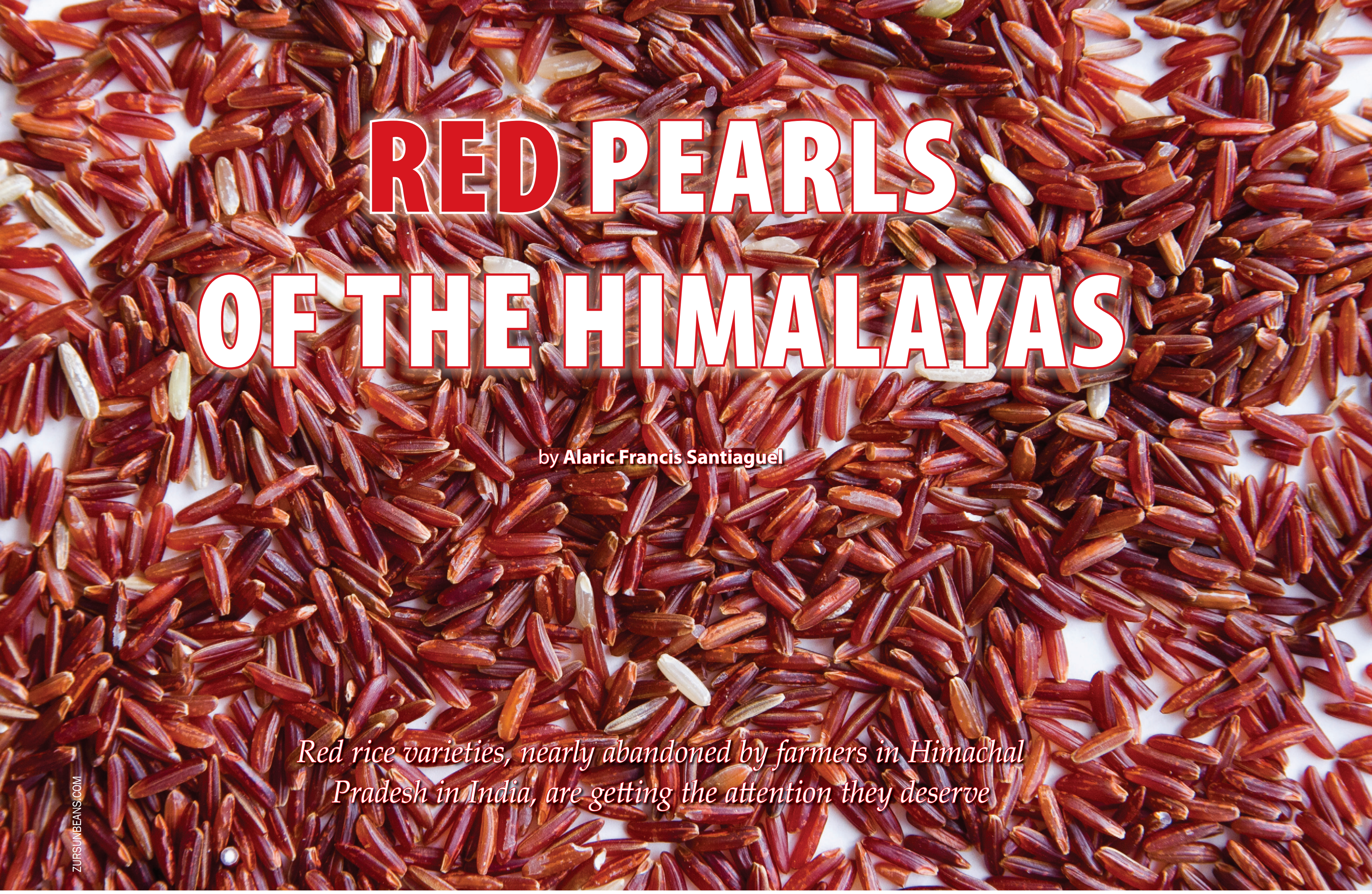
Note: The Chinese idiom *yī fàn qiān jīn* (one rice, thousand gold) is derived from this rice fable. It is a reminder that we should do favors for others without expecting anything in return, and we should forever remember a favor from someone else.

Dr. Ye is a collaborative research scientist at the International Rice Research Institute IRRI). He and his team are using modern technology to identify genes that will allow rice to tolerate heat and help farmers cope with global warming.

As a boy, Dr. Ye grew up on a farm in Yunnan, China and rice was the most important crop for his family. However, with traditional varieties and farming techniques, the yield was very low. His family and many families in his hometown didn't have enough rice to eat until the late 1980s, when he was already in high school. Later on, with new high-yielding rice varieties, especially hybrid rice, among other technologies, farmers were able to grow enough rice for their families. It's easy for him to relate with the poor boy in the story and he reminds himself to be of help to the poor and society.

Ms. Malabanan is an intern at IRRI and communication arts student at Laguna University, Philippines.





RED PEARLS OF THE HIMALAYAS

by **Alaric Francis Santiaguel**

Red rice varieties, nearly abandoned by farmers in Himachal Pradesh in India, are getting the attention they deserve

Himachal Pradesh, the northernmost Indian state on the southern slopes of the Himalayas, could be the closest thing to the mythical Shangri-La—a harmonious blend of earth and skies, mountains and valleys, and snows and water. The state's robust economy is comparatively better than India's national growth, according to a 2012-13 survey.[1] It was named the "best state in the country" in another survey, besting other states in education and health, among other indicators of development. Its agriculture is the engine that powers its impressive growth and contributes greatly to the total domestic product.

An important crop in Himachal Pradesh, rice is cultivated on about 80,000 hectares in 10 of the 12 districts of the state. Rice is cultivated in many agroclimatic conditions and ecosystems, from foothills (350 meters above sea level) to mid hills (1,000 m), to high hills (up to 2,200 m). About 80% of the area lies in the mid to high hills and around 60% is irrigated. The remaining is rainfed upland. The state's average rice yield is 1.5–1.7 tons per hectare.

A fortune in crimson

One of the many treasures of Himachal Pradesh is its red rice varieties. These include chhohartu from Shimla District; sukara, jhinjan, and karad from Chamba District; jattoo, deval, and matali from Kullu District; and desi dhan, kalizhini, achhoo, and begmi from Kangra, according to R.P. Kaushik, former head and rice breeder of the Rice Research Centre at Chaudhary Sarwan Kumar Himachal Pradesh (CSKHP) Agricultural University.

"These are cultivated mainly in high altitudes of the state," said Dr. Kaushik. "Based on molecular analysis, jattoo, matali, deval, desi dhan, karad, chhohartu, and bhrigu dhan are japonica types. Those adapted to low and mid hills are indica types."

Red rice varieties probably originated from the interbreeding of traditional white-grained varieties and annual weedy rice (*Oryza spontanea/fatua*), which coexist in rice fields, according to Dr. Kaushik.

"Himalayan red rice varieties command a higher price because of their excellent texture, aroma, flavor, and visual appeal," he added. They could prove to be an economic boon to farmers if these varieties find their own high-value market niche similar to basmati, a specialty rice.

Protected grain

Chhohartu is grown on more than 500 hectares in Chhohara and Ransar valleys of Rohru. Chhohartu is the first crop variety in the state to be

[1] Economic survey of Himachal Pradesh 2012-13. The Directorate of Economics and Statistics, Government of Himachal Pradesh. 202 p. Retrieved 15 January 2014.

registered under the Protection of Plant Variety and Farmers Rights Act in 2013. Hence, farmers from the valley who grow this variety are entitled to benefits from making plant genetic resources available to seed companies for the development of new plant varieties.

"This recognizes the efforts of the farming community who inherited this variety from their forefathers and have been cultivating and maintaining this variety from time immemorial," Dr. Kaushik said.

CSKHP is also trying to get the red rice registered under the Geographical Indications of Goods (GI) Act. Under the GI Act, only registered authorized users or residents in a certain area can use the popular product name (e.g., basmati rice). Registering red rice under the GI Act would enable the farmers and others to market their product around the world. This would help boost exports also. And, the ultimate gainer will be the growers, according to Dr. Kaushik.

Nutrition powerhouse

Dr. Kaushik, Usha Kumari, and Dr. Dhirendra Singh studied the nutrition profile of 16 red rice varieties collected from different parts of Himachal Pradesh along with two nonred checks. They found some of the red rice varieties to be nutritionally superior to other rice varieties, and particularly rich in iron and zinc. Unpolished deval, for example, contains 25.9 parts per million (ppm) of zinc compared with the two nonred rice varieties (21.9 and 15.0 ppm). Unpolished improved begmi, recently released for general cultivation as Palam lal dhan 1, is not only a high yielder but it contains 21.9 ppm of iron and 19.8 ppm of zinc while the two nonred checks contain only 11.1 of iron and 14.1 ppm of zinc. The red rice varieties they examined also had high anthocyanins and flavonoids (antioxidants).

These findings provide a scientific basis for the age-old practice of giving the excess water decanted after cooking red rice to pregnant ladies and children to drink. Many red rice varieties have been incorporated into traditional medicine for thousands of years. The people of Himachal Pradesh have used matali a lal dhan for treating blood pressure and fever, while kafalya is traditionally used for treating leukorrhea and pregnancy complications, according to Uma Ahuja, a plant breeder at Chaudhary Charan Singh Haryana Agricultural University in India.

Ingrained in the soul

In Indian culture, which traces back thousands of years, red rice is important in the life of its people. According to Dr. Kaushik, chhohartu is given as a gift on various occasions under different names. It is known as *poli* when given on occasions of happiness such as marriages, religious ceremonies, or the birth of a child. It is called *path* when given to a sick person, and *sattu* during times of sorrow such as death. The rice of this variety is served during community lunches and *yajnas* (sacrifice).

In *Red Rices—Past, Present, and Future*, a paper Dr. Ahuja wrote with Narender Chaudhary and Rashmi Thakrar, Dr. Ahuja described the complex practices involved in cultivating the red rice Jatu (jattoo):

> *In Himachal Pradesh, the entire process of cultivation of Jatu rice is a ceremonial affair. Seed soaking and preparation of land for transplanting are accompanied by the worship of the family deity "Ishtadeo." Before transplanting, the seedlings are placed at the entrances of temples. Before harvest, the ripe grains are first cooked and offered to the deity "Kuladeo." On this occasion, there is a tradition of distributing such cooked rice among family members, neighbors, and relatives. After the harvested grain is brought home, some rice is separately preserved for religious ceremonies associated with the gods. The cultivation of Jatu is done on fixed dates. The fields are prepared and seeds are soaked on the Sankranta (the beginning of a month or year) of Vaishaka (April-May). The grains are covered with the leaves of bhojpatra (*Betula alnoides*) for one month. On the next Sankranta, the sprouted seeds are put into the nursery area. Again on the Sankranta of Ashadha (June-July), transplanting is undertaken. From the Sankranta of Sawan (July-August) to that of Bhadon (August-September), weeding is carried out. The harvest of Jatu is started on the Sankranta of Kartik (October-November). The new harvest is eaten after the month of Magha (January-February).*

An ancient foundation for future varieties

The wide genetic diversity of traditional varieties is a potential resource for developing modern varieties with improved traits. Thus, the higher nutritional content of the red rice varieties of Himachal Pradesh could be used in breeding programs for boosting the nutrient content of rice.

"The soils of Himachal are highly acidic, in which iron is highly available. Traditional varieties probably accumulated genes for higher iron uptake during the course of their evolution over thousands of years," said Dr. Kaushik. "During the 40 years of my association with the rice crop, we did not come across any iron toxicity symptoms in traditional varieties, unlike in some semidwarf varieties introduced to the mid hills in the late seventies."

Mr. Santiaguel is associate editor of Rice Today.

MAP OF central Benin showing the assessed inland valley areas (red) and the digitized inland valley sections (bluish black) from the IMPETUS database superimposed on the Aster Digital Elevation Model.

Defining inland valleys in sub-Saharan Africa

by **Sander Zwart** and **Stefanie Steinbach**

Inland valleys—common landscapes in Africa—can play a vital role in future food security because they are more fertile than the surrounding uplands. Moreover, water is more available for a longer time. In many regions, two to three crops are harvested per year, while in the uplands only one crop can be cultivated. In rainy seasons, rice is the only major crop that can be grown in wet and temporarily flooded conditions. On the valley fringes, cash crops such as maize, cotton, cashew, mango, and banana are common.

To date, no reliable data exist on the total area of inland valleys in sub-Saharan Africa, the share of inland valleys already used for agricultural production, and whether or not they are suited for rice-based systems. This information is crucial for agricultural development interventions and for scaling out technologies efficiently.

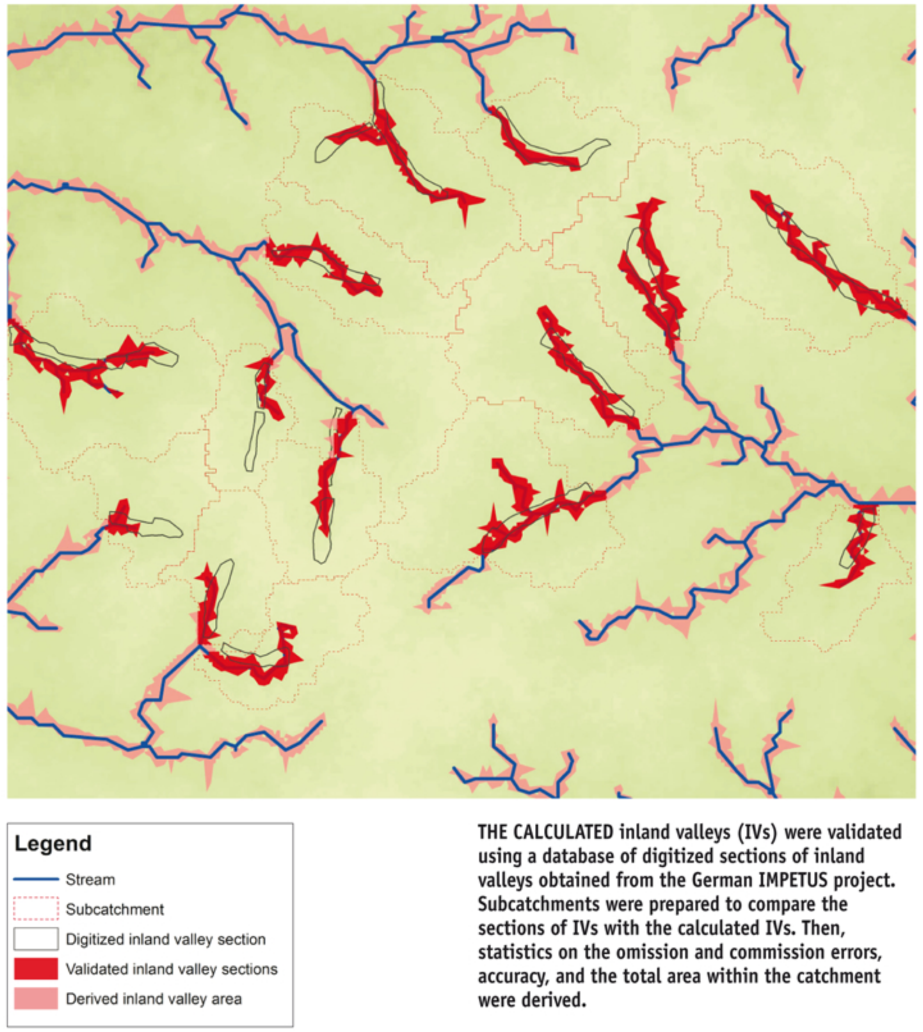
To fill these information gaps, Africa Rice Center has adopted a two-step approach. First, inland valley and lowland areas are mapped in ArcGIS, a geographic information system (GIS) for working with maps and geographic information using digital elevation models and advanced algorithms. Second, the potential of each inland valley is assessed using Random Forest statistical analysis and spatial modeling using biophysical and socioeconomic datasets.

A digital elevation model (DEM) provides a value for the altitude for each pixel. Two types have global coverage and are available for free to the research community. The Shuttle Radar Topography Mission (SRTM) DEM, which was developed by NASA, has a spatial resolution of 90×90 meters. The Aster (Advanced Spaceborne Thermal Emission and Reflection Radiometer) DEM is more precise in spatial resolution (30×30 meters), although its accuracy is lower than SRTM.

Starting with Benin, a small West African country, a model was developed to first assess the stream network based on digital elevation models. Then, virtual transects were created for each section of the stream to provide the altitudes of the stream, the lowest part, and the surrounding pixels of the valley. The inland valley was then determined by using three thresholds[1] representing the maximum elevation difference between the bottom and the pixels

that are attributed to the inland valley. This was then validated using a dataset of more than 300 digitized inland valleys in Benin from the IMPETUS project, a joint venture of the universities of Cologne and Bonn in Germany.

Findings show that the derived inland valleys have more than 45% accuracy for both Aster and SRTM DEMs. The closest estimation in terms of total area, an overestimation of 9%, is obtained with the Aster DEM and a threshold of 1 meter. Thus, the total inland valley area in Benin was estimated to be 12,000 km², which is about 10% of Benin's land surface. This study in Benin is the first of its kind. In the future, similar studies will be made for Sierra Leone, Liberia, Mali, Nigeria, Burkina Faso, and Togo. By 2016, validated inland valley maps and derived national and subnational statistics for all of West Africa will be available through web mapping services.



THE CALCULATED inland valleys (IVs) were validated using a database of digitized sections of inland valleys obtained from the German IMPETUS project. Subcatchments were prepared to compare the sections of IVs with the calculated IVs. Then, statistics on the omission and commission errors, accuracy, and the total area within the catchment were derived.

The authors acknowledge financial support from the European Commission through the RAP-IV project and from the Ministry of Agriculture, Forestry, and Fisheries of Japan through the SMART-IV project.

Dr. Zwart is a researcher in the Remote Sensing and GIS unit at AfricaRice in Benin. Ms. Steinbach is a graduate student in the University of Cologne's Department of Geography.

[1] A threshold is the simplest method of image segmentation.

AN INLAND valley with maize on the valley fringes (*foreground*), rice fields in the valley bottom (*middle*) and trees amidst natural vegetation on the other fringe (*background*).

Isagani Serrano

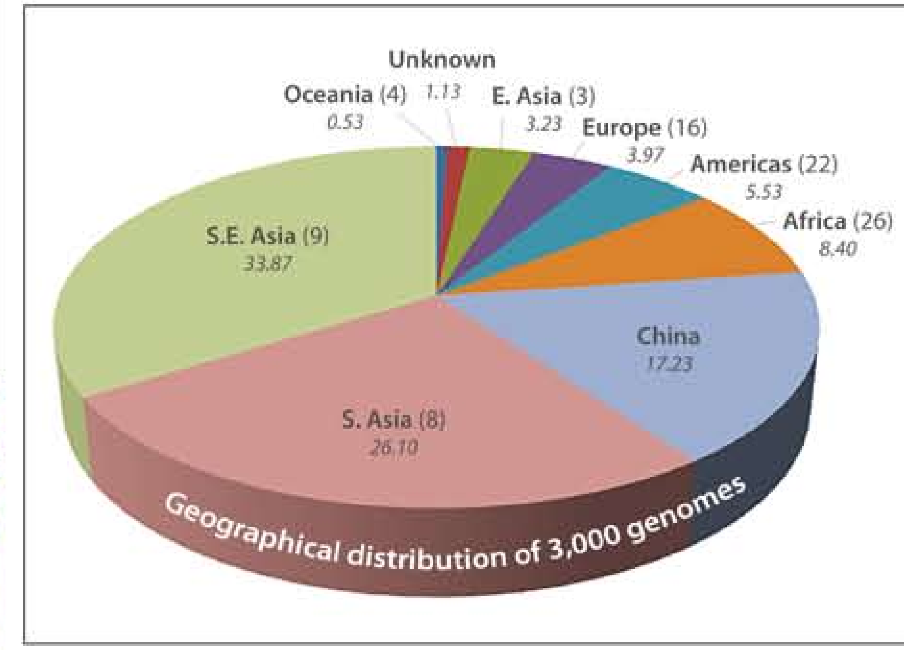
Bululs (rice gods) stand guard over heirloom rice in a storage shed in Banaue, Ifugao, Philippines. These choice bundles of panicles have been selected for future planting. This Ifugao rice, with its unique set of traits, is entry #1683 among the accessions in IRRI's International Rice Genebank selected for sequencing in the groundbreaking 3,000 Rice Genomes Project. See the following article about the project.

ISAGANI SERRANO (2)

Dawn of a new era in rice improvement

Compiled by **Gene Hettel** from ***GigaScience* articles** and additional interviews

With the sequences of 3,000 rice genomes now being made publicly available to researchers worldwide, the true power of rice genetic resources has been unleashed



GEOGRAPHIC DISTRIBUTION of 3,000 representative rice accessions whose genomes have been sequenced. Numbers in parentheses indicate the number of countries in each region.

Traditional rice varieties encompass a huge range of potentially valuable genes. These can be used to develop superior varieties for farmers to take part in the uphill battle of feeding an ever-increasing world population (estimated to reach 9.6 billion by 2050). The genes linked to valuable traits can help breeders create new rice varieties that have improved yield potential, higher nutritional quality, better ability to grow in problem soils, and improved tolerance of pests, diseases, and the stresses, such as flood and drought, that will be inevitable with future climate change.

Much of this diversity is conserved within the International Rice Genebank Collection (IRGC) at the International Rice Research Institute (IRRI). According to Ruaraidh Sackville Hamilton, head of IRRI's T.T. Chang Genetic Resources Center (TTC GRC), the IRGC now holds a global collection of more than 121,000 types or accessions of rice. Yet, breeders have harnessed only less than 5% of the germplasm collection there in active breeding efforts. "But all that is changing with a very exciting development to make the IRGC useful beyond our wildest dreams," he exclaims.

The 3,000 Rice Genomes Project

A single genome[1] cannot reveal the large stockpile of genetic diversity in rice and hence many potentially important genes are not present in the handful of lines that have been sequenced over the last decade. So, to drastically change this dynamic, IRRI—in collaboration with BGI in Shenzhen, China, and the Chinese Academy of Agricultural Sciences (CAAS)—has completed the sequencing of 3,000 rice genomes of varieties and lines representing 89 countries (see figure) now housed in the IRGC (82%) and CAAS's genebank (18%). "This is an unparalleled development in plant science for a major food crop," says Ken McNally, senior scientist in the TTC GRC and a project team member.

On top of that, the open-access, open-data journal *GigaScience* (produced by BGI and BioMed Central) published, on World Hunger Day 2014 (28 May), a data note[2] and commentary[3] on the 3,000 Rice Genomes Project (3K RGP). Most significantly, released at the same time was the project's entire 13.4-terabyte dataset in a citable format in the journal's affiliated open-access database, GigaDB (see box), which instantly quadrupled the previous amount of publicly available rice sequence data. The 3K RGP is funded by the Bill & Melinda Gates Foundation (BMGF) and the Chinese Ministry of Science and Technology.

According to Zhikang Li, project director at CAAS, the 3K RGP is part of an ongoing effort to provide resources specifically for poverty-stricken farmers in Asia and Africa. "We are aiming to reach at least 20 million rice farmers in 16 target countries (eight on each continent)," he says. "With decreasing water and land resources, food security is—and will be—the most challenging issue in these countries." Echoing Dr. Sackville Hamilton, Dr. Li says, "As a scientist in rice genetics, breeding, and genomics, it is a dream come true for me to help solve this problem."

"The population boom and the worsening climate crisis have presented big challenges on global food shortage and safety," adds Jun Wang, BGI director. "BGI is dedicated to applying genomics technologies to make a fast, controllable, and highly efficient molecular breeding model possible. The 3K RGP opens a new way to carry out agricultural breeding. Joining forces with CAAS, IRRI, and BMGF, we have made a step forward in big-data-based crop research and digitalized breeding. We believe this will get us closer to the ultimate goal of improving the well-being of the human race."

According to Robert Zeigler, IRRI director general, access to the sequence data of these 3,000 rice genomes will tremendously accelerate the progress of breeding programs.

[1] A genome is the genetic material of an organism (in the case here for each of the 3,000 selected rice accessions), which is encoded in its DNA and includes the genes and the noncoding sequences of the DNA.

[2] www.gigasciencejournal.com/content/3/1/7.
[3] www.gigasciencejournal.com/content/3/1/8.

Publication in *GigaScience* includes storage of relevant associated data in the journal's affiliated database, GigaDB (http://gigadb.org/dataset/200001), where every dataset is provided with a digital object identifier (DOI), making it possible to cite, find, and track data in standard scientific literature, which serves as a strong incentive for researchers to more rapidly release expensive and work-intensive datasets for community use.

On top of hosting this wealth of supporting data in GigaDB to provide the most extensive availability to the community, the sequence reads for this project have also been submitted to the repository of the European Nucleotide Archive: www.ebi.ac.uk/ena/data/view/PRJEB6180.

Enquires can be directed to the following members of the 3K RGP consortium:
Gengyun Zhang, BGI, Shenzhen, China
Zhikang Li, CAAS, Beijing, China
Tian-Qing Zheng, CAAS, Beijing, China
Kenneth L. McNally, IRRI, Los Baños, Philippines

"The collaborative 3K RGP," he says, "will add an immense amount of knowledge to rice genetics and enable detailed analysis by the global research community to ultimately benefit the poorest farmers who grow rice under the most difficult conditions."

To reach their goals, the three institutes have not only released the large volume of data, they are also making available through the IRGC seeds for each rice accession that has been sequenced. "Having available banked seeds is essential to make full use of this germplasm and the data about it," says Dr. Sackville Hamilton.

Speeding the breeding

A major part of the project is to directly link the genetic information (genotype) to the physical traits (phenotype) of these different accessions. This will require careful assessment and curation of each accession for the agriculturally important traits mentioned earlier, which breeders can then link to genetic markers in the now available genome sequences.

Current breeding practices, which have essentially remained the same since the development of agriculture, typically employ the observation of apparent physical traits to guide parent selection for making crosses with the hope that the offspring will show a new combination and an improvement of the desired traits. However, the underlying genetic makeup of the offspring can often confound breeders' expectations. So, they often have to resort to time-consuming trial and error involving multiple successive generations.

The 3K RGP data will provide a major step forward by helping breeders to take advantage of the natural trait variation that is found across the selected genebank accessions in the project. Knowing fully the genetic makeup of a particular rice accession will allow researchers to identify genetic markers related to specific traits, and better understand how different genetic interactions affect plant phenotypes. With this information, breeders will be able to make more intelligent choices in accession selection for making crosses, resulting in more rapid development of rice varieties for deploying in poor and environmentally stressed locations around the world.

THE CORE 3K RGP team at IRRI involves (*left vertical row from top*) Nickolai N. Alexandrov, Ma. Elizabeth B. Naredo, Maria Socorro R. Almazan , Flora C. de Guzman, and Ruaraidh Sackville Hamilton; (*right vertical row from top*) Renato A. Reaño, Hei Leung, Grace Lee S. Capilit, Ramil P. Mauleon, Kenneth McNally, and Sheila Mae Q. Mercado. Jauhar Ali and Myla Christy Rellosa are not pictured..

According to Hei Leung, IRRI principal scientist and team member, the IRRI 3K RGP team is committed to moving quickly to take the sequence data and make detailed analyses. "Through the Global Rice Science Partnership (GRiSP), IRRI is leading the development of an informal global effort—the International Rice Phenotyping Network—to systematically evaluate the 3K RGP sequenced lines and to connect plant performance to specific genes," he says. "By closely integrating these resources into breeding programs based on modern molecular breeding and selection strategies, varietal development in hundreds of rice breeding programs will be accelerated over the next five years, delivering improved varieties to farmers and consumers at a faster pace than before."

AXA-endowed scientist to join the team

"In addition to working closely with GRiSP, BGI, and CAAS," Dr. Leung adds, "we have a head start with the timely arrival of Dr. Rod Wing, who was recently appointed to IRRI as an AXA-endowed scientist for genome biology and evolutionary genomics."

The AXA Research Fund, which encourages scientific research that would contribute to understanding and preventing environmental, life, and socioeconomic risks, currently supports more than 400 research projects like the 3K RGP in 30 countries.

UNIVERSITY OF ARIZONA

DR. WING, a professor at the University of Arizona and director of the Arizona Genomics Institute, has joined IRRI as an AXA-endowed scientist working with the 3K RGP team.

"Dr. Wing, an internationally recognized leader in the fields of plant genomics, bioinformatics, and evolutionary biology and particularly interested in genome data, is now part of the IRRI team and he will greatly enhance our capability to analyze the 3K RGP sequence data for gene and trait discovery," says Dr. Leung.

During a seminar that concluded an exploratory visit to IRRI in April-May 2014, Dr. Wing said, "Enormous challenges exist in bridging the gap from the discovery of genotypic and functional diversity to the release of superior varieties to farmers. So, it is a privilege to be at IRRI over the next five years because I want to help translate the rice genome biology of the 3K RGP into practical solutions for rice farmers. This will involve developing high-quality reference genomes for the five distinct varietal groups of rice, namely, tropical japonicas, indicas, aus/boro, basmati/sadri, and intermediates."

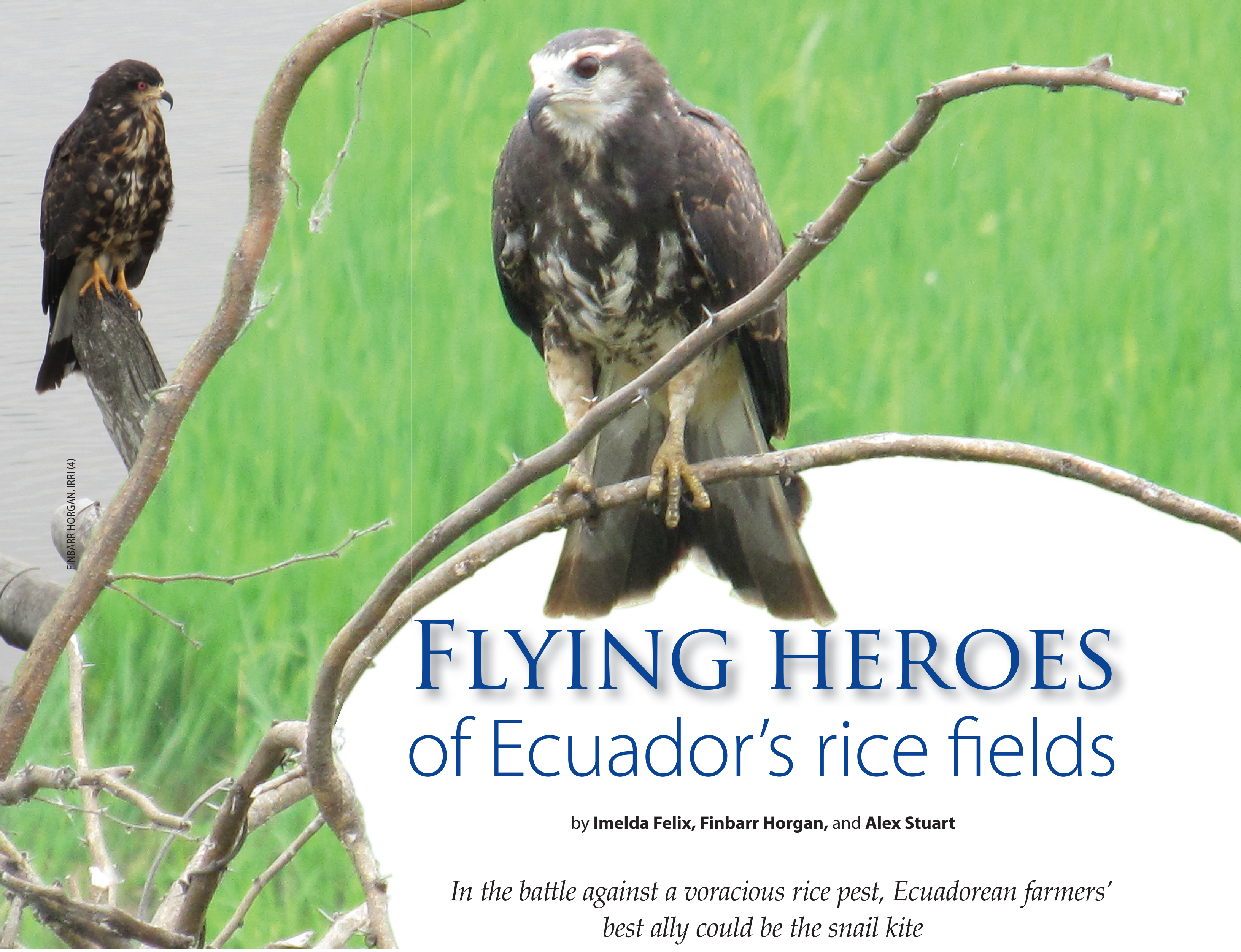
Beyond the 3K RGP, Dr. Wing is also interested in working with IRRI scientists to tap into the potential gold mine of wild rice diversity by analyzing genome sequence data of some of the more than 6,000 unexploited accessions of these species in the IRGC.

More genomes can be sequenced if necessary

"After reviewing the results coming out of the 3,000 genomes currently sequenced, we will determine whether we can identify a significant number of critical genes for use in rice improvement," concludes Dr. Leung. "At that point, we will decide how many more of the remaining nearly 180,000 accessions in the IRGC and CAAS genebank we may need to sequence and analyze."

Mr. Hettel is editor-in-chief of Rice Today.

See a video clip about AXA scientist Rod Wing at http://youtu.be/J4oUQV0gFPA.



FINBARR HORGAN, IRRI (4)

Flying heroes of Ecuador's rice fields

by **Imelda Felix, Finbarr Horgan,** and **Alex Stuart**

In the battle against a voracious rice pest, Ecuadorean farmers' best ally could be the snail kite

Apple snails (*Pomacea* spp.) have been a problem for Asian rice farmers for decades. First introduced in the late 1980s to Taiwan and the Philippines, these snails have now spread to most countries in Southeast Asia, as well as East Asia, such as Japan and Korea, where they are among the most damaging pests of rice and other aquatic crops. Recently, established populations of apple snails were found close to major rice-growing regions in Pakistan. India, and Bangladesh. While a few other Asian countries are still free of apple snails, what can these countries expect should the snails someday arrive?

Events in Ecuador might give some clues. In 2005, rice damaged by apple snails was first noticed in Ecuador. Since then, and particularly after severe flooding in 2008, the snail has spread to most of Ecuador's major rice-growing regions. Losses to the rice sector from apple snails in 2013 alone were estimated at over US$56 million. However, Ecuadorean rice farmers have one big advantage in dealing with apple snails over their Asian counterparts—the snail kite (*Rostrhamus sociabilis),* a predatory bird that specializes in eating snails.

Flying pest control

The snail kite's natural range extends from Florida in the United States to subtropical region in Argentina, a region that is also the native habitat of several apple snail species, including the most invasive species: the golden apple snail. West of the Andes, snail kites are largely restricted to mangrove swamps and river estuaries in southern Ecuador, where they likely feed on less invasive snails such as the spike-topped snail.

Prior to the recent apple snail invasion of Ecuador, snail kites were a threatened species. Their population had declined dramatically because of habitat loss and the overuse of agrochemicals. Moreover, farmers often hunted and killed the birds, believing that they damaged livestock. In recent years, as the apple snails have continued to spread, snail kites have become a common feature of the Ecuadorean rice landscape and a welcome sight for farmers. Groups of these birds can be regularly seen perched over rice fields watching for snails, communicating with one another through haunting, rolling caws, or swooping down to catch the snails before gracefully flying off with their prey.

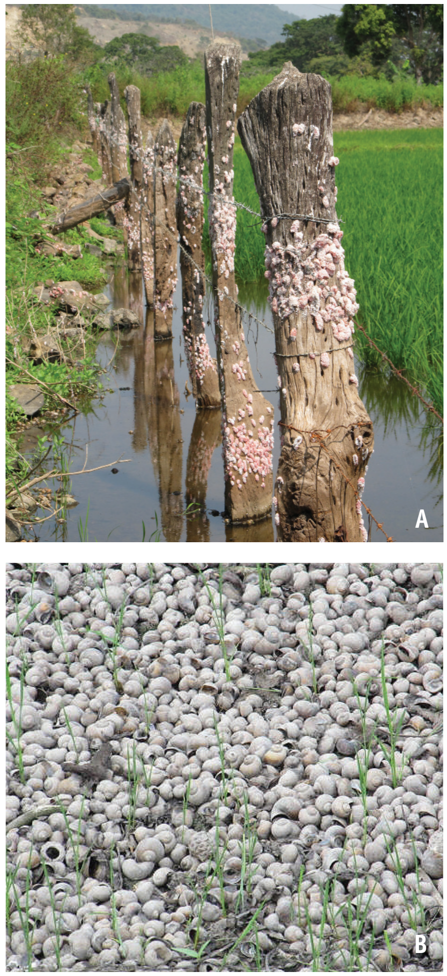
But are snail kites enough to control the snails? We found out that the snail kites first respond to high snail densities by building up their own populations. This means that the snail kites require ample food and suitable habitat for hunting and nesting. Thus, for some time, as the apple snails spread, they escaped the predatory snail kites.

During this time, snail densities peaked, and had terrible effects. A visit to any newly snail-invaded region is a lesson in an ecosystem out of balance: hundreds of bright pink egg masses, containing millions of eggs, can be seen on wooden posts or the trunks of trees near infested ponds and paddy fields. Large patches of rice fields, where the water is deepest, become denuded of rice and other aquatic weeds. Snails, the size of small apples, chew through any remaining green vegetation and decomposing matter at the water's edges.

Desperate chemical measures

Agrocalidad, Ecuador's agricultural extension service, has been working with farmers to control snail damage to rice. Experience in Asia had shown that delayed transplanting of rice plants, careful control of water depth, and other cultural control methods could help reduce snail damage. Agrocalidad has shared these methods with tens of thousands of farmers through workshops, talks, theater, videos, posters, and handbooks. However, although Agrocalidad discourages the use of highly toxic insecticides, farmers overwhelmingly used these chemicals, particularly endosulfan, to kill the snails. This reduced snail densities but at high environmental and health costs. Worst of all, farmers noted that the chemicals were also killing their greatest allies—the predatory snail kites. In 2011, the government of Ecuador banned the use of endosulfan, and promoted the use of a more selective molluscicide, methaldehyde—for which the effects on snail kites are still unknown.

Overall, 2013 seems to have seen a decline in snail numbers in some affected areas, particularly in fields at higher elevations. However, a large part of Ecuador's rice is produced during the dry summer months (June-December) in *vegas*. Vegas are natural wetlands that are completely flooded for 6 months of the year. In June-July, the water recedes, and farmers track the water levels and plant their rice in a sequential manner in areas of shallow water. This results in an attractive rice landscape with rice of different stages in natural patterns (a system called *arroz escalonado* or stepped rice). Apple snails in *vega* systems have remained at very high densities and continue to damage rice significantly. Furthermore, these habitats are highly vulnerable to agrochemicals because they are the natural habitat for a diversity of amphibians, fish, birds, and other fauna and flora.



BELIEVED TO have been deliberately introduced to clear invasive water hyacinths, apple snails are a lesson in an ecosystem out of balance. A) Posts covered with apple snail eggs indicate extremely high snail densities—a huge problem for Ecuador's rice farmers. B) Snail shells in a drained rice field look like mounds of pebbles. Apple snails have been difficult to control in low-lying rice fields that are flooded during the wet season.

For scientists, the events in Ecuador are an opportunity to better understand how snails invade rice and how predators and prey interact with each other. Continued monitoring of the situation will highly benefit both scientists and farmers, and could help predict future effects and help design management options as apple snails continue to invade new areas.

Above all, the tremendous negative impact of the invasive apple snail on the Ecuadorean rice sector, despite the presence of a key predator, should encourage snail-free rice-producing countries to be vigilant against possible infestation by tightening quarantine regulations and banning the trade and import of exotic snails. The best way by far to avoid apple snail damage is to ensure that these voracious snails are not introduced to any new regions, where, without natural predators such as snail kites, losses to the rice sector could be even more severe than those experienced in Ecuador.

Ms. Felix heads the Crop Protection Unit of the Agencia Ecuatoriana de Aseguramiento de la Calidad del Agro (Agrocalidad) *in Guayas Province, Ecuador. She has coordinated Agrocalidad's response to mollusk invasions (including apple snail, giant African snail, among others) since 2010.*

Dr. Horgan is a senior scientist in the Crop and Environmental Sciences Division (CESD) at IRRI. His work focuses on understanding the causes of pest outbreaks in rice from ecosystem and management perspectives. Dr. Stuart is a post-doctoral fellow at CESD. He is an ecologist working on IRRI's project, Closing Rice Yield Gaps in Asia with Reduced Environmental Footprint (CORIGAP).

The seven samurai of Latin American rice improvement

by **Ricardo Labarta** and **CIAT's impact evaluation team,** with **Nathan Russell**

Seven countries are pushing the rice breeding envelope in the region and reaping big rewards

They're not the biggest rice producers in Latin America and the Caribbean (LAC). But, like the seven samurai of the famous 1954 adventure film, they're certainly among the boldest, and they fight hard to improve the lot of rice-growing communities.

These seven countries are Bolivia, Costa Rica, Ecuador, Nicaragua, Panama, Peru, and Venezuela. Their national programs are currently engaged with the impact evaluation team at the Colombia-based International Center for Tropical Agriculture (CIAT) in a study on the adoption of improved rice varieties, CIAT's role in their development, and their impacts on rice productivity.

IMPROVED RICE lines ready for transplanting in Peru.

CIAT (3)

Steady acceleration

CIAT's collaboration with these seven programs has become especially strong over the years. Their experience and achievements illustrate particularly well how strengthening national capacity has accelerated the development of improved varieties.

Today, the LAC region is producing around 27 million tons of paddy rice with an average yield of 4.8 tons per hectare, compared to only about 12 million tons of rice in 1970, with an average yield of 1.8 tons per hectare. This impressive growth is the result of the adoption of improved modern varieties as well as better agronomic management. In 1971, CICA 4—an elite line developed by CIAT and distributed through the International Rice Testing Program—was released in Colombia. One decisive factor has been the steady improvement in national rice research capacity. Before 1990, the seven countries together were releasing just 1.2 varieties per year, on average, or 0.2 varieties per country. Then, in the 1990s, the number rose to 4.6 varieties per year (0.7 varieties per country) and to 6.8 varieties annually after 2000 (essentially one variety per country). Of the 186 rice varieties released by the "seven samurai" countries, 63% were developed using germplasm from CIAT.

Throughout the 1990s, CIAT's involvement in variety development consisted mainly of transferring advanced lines and a few segregating populations generated at Center headquarters to national breeding programs. These materials were then evaluated under diverse production conditions, and the selected lines were released as improved varieties.

But, over the last decade, many national rice programs have begun making their own crosses, using parents from CIAT and other sources, especially the International Rice

CECILE GRENIER, a CIRAD breeder working at CIAT, and Jaime Borrero, a CIAT research associate, inspect a rice field in Bolivia.

Research Institute (IRRI). Since 2000, 66% of the varieties released in the seven countries have resulted from crosses made by national rice programs. Thus, CIAT's contribution to rice variety development in these countries has increased to 75% of the varieties released, even as the transfer of advanced lines from Center headquarters has declined.

Growing strength

Despite the proliferation of modern rice varieties across the region, some countries still show significant gaps in the adoption of these varieties. The seven countries covered by the CIAT-led study reported that about 60% of the total rice area is sown to varieties released after 2000. The age of these varieties averages 8.4 years. But, these averages disguise large variability across countries. Although 93.4% of Panama's rice area is planted to varieties released in the last decade, the figure is only 15.1% for Nicaragua. Similarly, although in Venezuela the average age of rice varieties currently grown is just 5.7 years, in Bolivia it is around 11.5 years.

"In the case of Venezuela, the dynamism mainly results from good breeding programs in both the public and private sector," said Eduardo Graterol, executive director of the Latin American Fund for Irrigated Rice (FLAR, its acronym in Spanish). "The country's strong certified seed system also contributes importantly, supplying seed for more than 80% of the total rice area."

The growing strength of national rice breeding programs and their continuous investment in genetic improvement have helped farmers achieve sustained yield increases across the region. Harvests in southern Brazil, Peru, and Uruguay now average more than 7 tons per hectare.

"In Peru, the decisive factors are the productive potential of new varieties, their tolerance of stress, good grain quality, and a short growing period as well as the innovative character of our growers," said Orlando Palacios, who leads rice research in the country's National Institute of Agricultural Research (INIA).

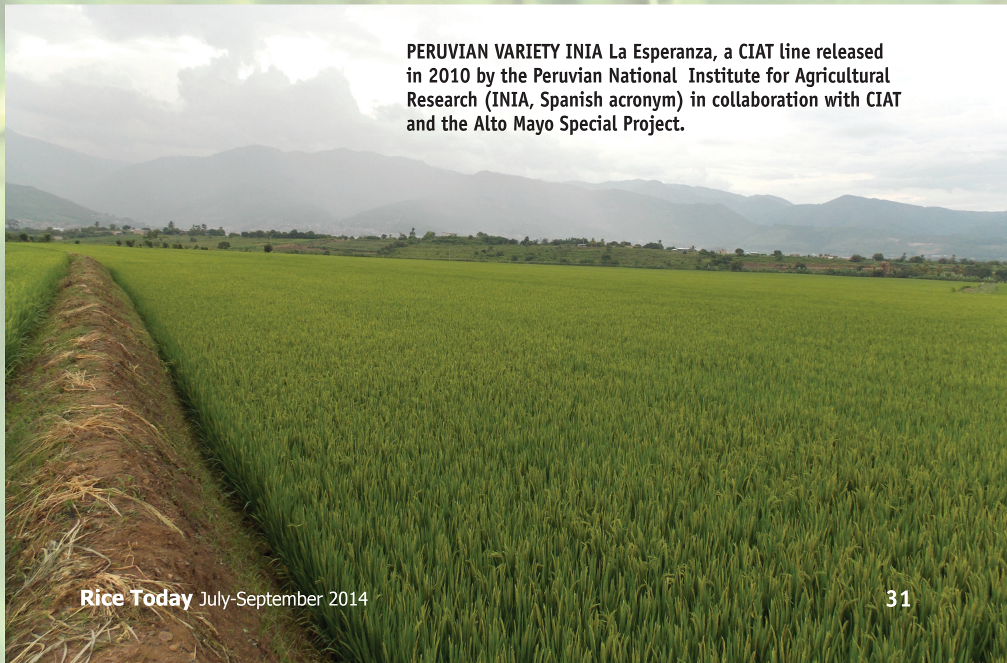
Substantial payoff

CIAT's work on genetic improvement has contributed significantly to the gains. In six of the seven countries participating in the ongoing adoption study, the average yields of the improved varieties to which CIAT contributed are 13% higher than for other improved varieties. Peru is the single exception because of its high-yielding variety IR43, which was developed by IRRI, selected at CIAT, and introduced by the Peruvian national program for the country's northern coast, a major rice-producing area.

These results show the substantial payoff from international rice genetic improvement for LAC and the value of CIAT's leadership in this work. And, the study highlights the success of efforts to strengthen the capacity of national rice programs, while calling attention to the need for redoubled efforts in certain countries, such as Bolivia and Nicaragua. To maximize the benefits from rice genetic gains, the region must also sharpen its focus on reducing yield gaps through improved crop management.

Continued advances in rice genetic improvement and agronomy are the keys to sustaining the impressive growth in yield and production that has made Latin America not only self-sufficient but also a net exporter of this important cereal.

Dr. Labarta is an agricultural economist and Mr. Russell is the head of Communications and Knowledge Management at CIAT.



PERUVIAN VARIETY INIA La Esperanza, a CIAT line released in 2010 by the Peruvian National Institute for Agricultural Research (INIA, Spanish acronym) in collaboration with CIAT and the Alto Mayo Special Project.

Smitten by science

by **Bianca Paula Ferrer**

They found one another through science—and love has kept them together ever since

Krishna Jagadish and Impa Somayanda were studying at the same university in Bangalore, India, before they joined the International Rice Research Institute (IRRI) in the Philippines in 2006. But, their paths did not cross during this time. "In fact, Impa's PhD supervisor was my teacher so we were basically taught by the same person," said Krishna. It took at least another three years for the two to cross paths.

IRRI (4)

KRISHNA JAGADISH, Impa Somayanda, and their son Kanav prove that rice science and love do mix.

Close encounters of the scientific kind

After completing his master's degree in India, Dr. Jagadish decided to pursue his PhD between the University of Reading in the United Kingdom and IRRI. Meanwhile, after completing her PhD from the University of Agricultural Sciences in Bangalore, Dr. Somayanda decided to join IRRI in 2006 as a postdoctoral fellow in drought physiology.

In 2007, Dr. Jagadish joined IRRI as a visiting research fellow to continue working on proteomics under Dr. John Bennett. Later, he was appointed as a postdoctoral research fellow for three years. During this period, he met Dr. Somayanda. Dr. Jagadish decided to spend his Christmas of 2007 at IRRI while Dr. Somayanda, for work-related reasons, also chose not to spend the holidays with her family. "I remember we started off as friends," she said. "That was when we got to know each other really well."

On one occasion, Dr. Jagadish was working on a research paper but was unsuccessful in getting the manuscript published. The paper needed some improvements in mapping what breeders call quantitative trait loci or QTLs, which are minute bits of genetic information. The problem was that, although he could map QTLs using a program that ran on the now defunct disk operating system (DOS), he couldn't map them using a program that ran on the more advanced Microsoft Windows.

"Basically, over two weeks, she would spend her time from 6:00 p.m. till 10:00 p.m. trying to sort out aspects essential for improving the manuscript," said Krishna. "When I resubmitted the paper, it just got accepted right away without any comments. She's good at what she does. She's generally a silent person, but she's very effective. So, I guess that was one of the reasons why I secretly admired her."

It's complicated

Sharing the same interest in science drew the two closer together. In 2008, they decided to marry. But, things got complicated, especially back home in India.

"Impa comes from a clan which is extremely open to others outside theirs, but equally conservative when it comes to marriage," explained Krishna. He was from Kolar, one of Karnataka's towns, while Dr. Somayanda was from the more idyllic town of Coorg, also in Karnataka. Coorg and Kolar couldn't be more culturally divergent. The local language, festivals, the way the people dress, and even the wedding rituals of the two towns were strikingly different.

"It was pretty challenging," said Krishna.

One couple, two weddings

It took almost a year for her parents to give them their blessing. But her mother couldn't have been happier seeing them initiate the engagement ceremony to the marriage. "You know, after all, that's how parents are," Impa said.

KRISHNA JAGADISH and Impa Somayanda are leading experts in the field of plant physiology. He studies the effect of high day and night temperatures on rice while she looks at how rice absorbs the important nutrient zinc.

When they got married, two separate wedding ceremonies were held, one in Coorg and the other in Kolar.

Dr. Jagadish fondly recalled his surprise when they were wed in Coorg. "Across all South Indian marriages, you'll never find meat, alcohol, or dancing," he said. "But, during our wedding, there was a continuous flow of alcohol, loads of meat dishes, nonstop music, and dancing."

"Throughout that whole process, which took two days, I was anxious because marrying outside our clan was rare," confided Impa. "Fortunately, everything went smoothly. For Krishna's relatives, everything was new. They all enjoyed it so much that they remembered it well and were able to recall their experiences whenever we met them."

The newlyweds then exchanged vows again in Kolar.

"Our second wedding ceremony in my hometown was exactly the opposite," said Krishna. "But, I didn't really mind the way we got married, as long as we had the certificate to live together thereafter."

Perfect match

The couple soon headed back to the Philippines and settled into their new life together at IRRI after finally getting married in India.

"Having Impa as a partner both personally and professionally was like having the best possible friend," said Krishna. "She's very passionate about her work so that was good for our relationship. She's happy to hear about what I do, and most of the time she would give me useful suggestions."

THEY LOVE each other so much they got married twice! Krishna and Impa wearing traditional wedding attire at one of their wedding ceremonies.

They could solve a lot of work-related problems between the two of them. For example, if they were driving home for lunch, he would tell Impa any scientific dilemma on his mind. Their discussion would help him come up with ideas to work on after returning to work.

Sometimes it's Impa who gets ideas from him. She has also received a lot of help on scientific writing from Krishna on many occasions. "He is good at it," she noted. "Now I write much better than before after taking tips from him and also following closely how he writes."

Scientific niche

Earlier in their careers, both of them tried going into genomics—studying how plant mechanisms work at the molecular level. But they quickly realized that this wasn't their cup of tea.

"So I just moved back into my area of specialization and it's the same with Impa also," said Krishna. "After a few attempts to get into the molecular side of research, she quickly realized that her strength was in physiology and she has from then on stuck to her strength.

"We went back to actual physiological understanding of plants rather than focusing exclusively on things at the molecular level, which we manage through internal and external collaborations," he added.

"Krishna started here at IRRI as a PhD student," said Impa. "Now, he serves as a scientist and deputy division head of the Crop and Environmental Sciences Division. He manages around 20 people and has made some progress with his research on high day- and night-time temperature stress in rice. But, I think there's still a long way to go.

"I work as a project scientist on physiology and soil chemistry of zinc uptake, transport, and loading into rice grains," she continued. "We love the kind of work that we do and the people we work with and that's what has kept us going at IRRI all these years."

Dream fulfilled

On 2 January 2014, Krishna and Impa fulfilled a lifelong wish. It wasn't a scientific discovery, but a healthy baby boy they named Kanav, which means "dream fulfilled" in Sanskrit.

"I remember watching a Bollywood movie and then I heard the name 'Kanav' from one of the characters," said Impa. "I liked it the first time I heard it so I decided to look it up on the Internet. After I learned what it meant, I told Krishna. He liked it so we decided to go for it."

Ms. Ferrer is a science communication specialist at IRRI.

A game changer in Africa's rice agronomy

by **Savitri Mohapatra**

From the football field to rice fields, Kazuki Saito is proving to be one of Africa's most valuable players

It is difficult for colleagues to believe that once upon a time Kazuki Saito, an agronomist at Africa Rice Center (AfricaRice), was more enthusiastic about American football than about agricultural science. He confesses that, during his undergraduate years at Kyoto University, when he joined the university's American football team, he probably spent more time in the field than in the classrooms.

"However, I learned some valuable lessons from the game and I still use some of the strategies and insights from it to achieve goals at work," remarks Dr. Saito.

He has been able to bring the same energy, passion, and single-mindedness that helped him succeed as a player to his field research to achieve impact on the ground.

Farming roots

Dr. Saito was born in a rice-farming family in Niigata, Japan—home of the world-famous *Koshihikari* rice. His father, who is head of a rice farmers' cooperative in Tainai City in Niigata, continues to grow this variety. Given such close affinity to rice, it was only fitting that Dr. Saito took up rice science for his studies and career when he grew up.

After completing his degree, his supervisor, Takeshi Horie at Kyoto University, recognizing his sharp, analytical mind and determination, asked him to join an agricultural research project in Laos as part of his master's degree.

Turning point

This proved pivotal for Dr. Saito's future. His experience working with poor farmers who grow upland rice on hillside fields in northern Laos kindled in him an enduring passion for results-driven field research that can help make a difference in the lives of such farmers.

For his master's and doctorate degrees, Dr. Saito's research in Laos focused on evaluating different low-input cropping systems using legumes as short-duration fallow crops to improve soil fertility, reduce weed pressure, and sustain rice yield as part of a collaborative project of the International Rice Research Institute (IRRI), the national program in Laos, and Kyoto University.

Going against the tide of prevailing scientific opinion that improved varieties were not a suitable option to increase upland rice yield in that region, Dr. Saito tested improved upland rice varieties comparing them with traditional varieties. His study showed that the improved varieties out-yielded the traditional varieties by more than 70% and were also responsive to nitrogen fertilizer application. These varieties have now been widely disseminated to farmers.

His research in Laos was quite grueling because of the distance between field sites, which often could be reached only on foot through the mountain trails. His training as an American football player must have come handy during those days. Based on his PhD research, Dr. Saito eventually published eight peer-reviewed papers.

Moving to Africa

After completing his PhD, Dr. Saito made a big decision to conduct his postdoctoral research in Africa instead of working as a lecturer in Japan. Again, he was guided in this decision by Professor Horie, who was a Board member of AfricaRice at that time and was a strong supporter of rice research and development in Africa.

"Also for a researcher, it is more interesting and challenging to work on rice in Africa than in Japan," says Dr. Saito.

Since 2006, when he joined AfricaRice, Dr. Saito has worked on improving yield potential, and abiotic and biotic stress resistance in rice, with emphasis on phosphorus deficiency, iron toxicity, drought, and weeds.

Transferring experience from Asia to Africa

Building on his successful experience in northern Laos, Dr. Saito introduced improved *indica*-type and *aus*-type upland varieties in West Africa

R. RAMAN, AFRICARICE (3)

Clockwise from above

KAZUKI SAITO (*right*) shows the RiceAdvice to partners.

AS COORDINATOR of the Africa-wide Rice Agronomy Task Force, Dr. Saito helps introduce rice transplanters across Africa.

DR. SAITO'S WORK has led to a refocus of upland rice breeding work at AfricaRice, which now includes *aus* and *indica* materials.

and demonstrated their good performance during his initial years at AfricaRice. His work has led to a re-focus of upland rice breeding work at the Center, which now includes *aus* and *indica* materials.

He also conducted extensive research on weed competitiveness, which showed that upland *indica* and *aus* could be a useful source for improving both yield potential and weed competiveness. Recently, he also found that such materials have strong phosphorus deficiency tolerance.

A driving force

Today, Dr. Saito is the driving force behind the Africa-wide Rice Agronomy Task Force, launched in 2011. The Task Force brings together the resources of rice agronomists across Africa to improve rice productivity by introducing, testing, and disseminating baskets of good agronomic practices, decision support systems, and small-scale machinery. He leads task force activities in 21 countries across Africa in close partnership with national research institutes.

He has recently developed a decision-support application for

providing farmers with field-specific nutrient management guidelines called *RiceAdvice*. The tool is based on similar agronomic principles as IRRI's *NutrientManager*. It can be used offline to enter information and get immediate responses and is now being tested in more than 10 countries.

Dr. Saito is also leading an AfricaRice team that has assessed yield gaps for rice in nine African countries in the Global Yield Gap Atlas project. A first version of a yield gap map for Africa can be accessed at www.yieldgap.org.

He has been actively involved in training more than 120 researchers, extension workers, and undergraduate students, in agronomy-related topics. He has also cosupervised or provided scientific backstopping to eight PhD students.

Research output

Dr. Saito has authored and co-authored 46 scientific papers in peer-reviewed journals and as book chapters. "These papers are all based on solid field agronomy work of direct relevance to food security," says Marco Wopereis, AfricaRice deputy director general.

Dr. Saito received the first prize in the category of Outstanding Paper and Presentation Award at the 3rd Africa Rice Congress, Yaoundé, Cameroon, in 2013. Recently, he was among three coauthors who received the Best Paper Award from the Japanese Society of Crop Science.

Persistence and hard work

Dr. Saito's persistence and hard work have rubbed off on others he worked with and have earned him a great deal of respect.

In December 2010, Dr. Saito flew to Japan to undergo a lengthy operation to remove a brain tumor. Throughout this stressful period, he remained calm and dedicated to his work, checking the status of field experiments through his AfricaRice colleagues, and analyzing data. Two months later he was back in the field.

"Dr. Saito has shown stamina, determination, and leadership in conducting field research, in close collaboration with researchers and farmers, leading to tangible results often under difficult circumstances," says Dr. Wopereis. "Because of his ability to see the big picture, he is able to provide direction to rice agronomy research in Africa, even at his relatively young age."

Ms. Mohapatra is the head of the Marketing and Communications at AfricaRice.

More than seeds

by **Lanie C. Reyes**

Aside from receiving seeds of climate-smart rice, farmers in a flood-prone village inIndia also learn how to grow them properly and maximize their potential yield

SUDHANSHU SINGH (*in checkered shirt*) talks with the farmers in a village in Odisha to monitor the performance of flood-tolerant Swarna-Sub1 (*background*) after it went through a flood.

IRRI (2)

Sri Premananda Swain, a farmer from Arapada Village, Balipatna Block, Khurda District in Odisha, did not mind that it had rained for a short while earlier that day. Long ago, rain bothered him a lot. He knew that if rain continued to pour a little harder and for a longer time, it meant disaster. Floods could bring all his efforts to nothing when his rice crop was under water. The village has around 40 households and most of them, like Mr. Swain's, have small and marginal farmers who depend mainly on farming rice as their main crop. But, flooding is so common in his village because it is located near the river Dhanua.

In India, about 5.36 million hectares are flood-prone. In South Asia, it is about 12 million hectares. In fact, almost half of South Asia is rainfed and is prone to climate change-related problems such as flooding, salinity, and drought.

Fragile lands

"Rainfed," Sudhanshu Singh, scientist at the international Rice Research Institute (IRRI), stressed the word. The gloom in his voice became obvious as he recited a litany of words usually associated with rainfed.

"Low and fragile productivity; marginal and small landholdings; poor farmers; little use of inputs; more dependence on traditional varieties; less availability of quality inputs, including seed; a poor extension network; and slow adoption and diffusion of new technologies," he said.

These are the reasons why most of these areas were left uncultivated and unproductive. But Dr. Singh believes that well-planned actions and increased efforts are crucial in overcoming the constraints in these environments.

Climate-smart rice varieties developed at IRRI and multiplied and distributed under the Stress-Tolerant Rice for Africa and South Asia (STRASA) project, are already creating a major impact and have improved the lives of 10 million farmers in South Asia and Africa.

Room for growth

The usual yield of climate-smart rice such as Swarna-Sub1, a flood-tolerant variety, is generally around 5 tons per hectare according to Dr. Singh.

"This is already a one-half-ton to one-ton yield advantage over traditional varieties under normal conditions, meaning no can add as much as half a ton to one ton of yield."

Thus, in 2011, Dr. Singh started a project, funded by the European Commission (EC) through the International Fund for Agricultural Development (IFAD) that focuses on promoting appropriate management technologies to complement climate-smart rice varieties.

"These technologies will further improve the productivity of flood-prone and salt-affected rainfed lowland areas in South Asia, make rice production stable, and increase the income of resource-poor farmers," he said.

Changing a village

With this goal in mind, Dr. Singh's team from IRRI and partners from the Association for India's Development, headed by Dr. J. K. Roy, nodal scientist of the project, visited Arapada Village during the kharif (wet) season of 2012 to introduce improved nursery management practices for Swarna-Sub1.

Although the farmers use nitrogen and phosphorus fertilizers in seed beds, they also had a few misconceptions about fertilizing. They didn't use potassium because they believed that potash can make the roots of the seedlings grow so much that it would be difficult for contracted laborers to uproot them during transplanting. The farmers were afraid that this would increase the labor cost.

The demonstration plots showing the proper use of fertilizer, however, convinced the farmers to adopt the program and start applying fertilizer at the recommended rate of 45-45-45 kg NPK per hectare in their seedbeds.

That year their yield increased. The farmers who adopted the nursery management had an average yield of 5.6 tons per hectare. Mr. Swain himself harvested 7.5 tons per hectare.

In his local Odiya language, Mr. Swain raved about the importance of having healthy seedlings. He testified how changing his crop management

SUNHANSHU SINGH (*left*) and his team are helping farmers in a flood-prone area. The background shows fields planted to Swarna, a flood susceptible variety, after 10 days of complete submergence.

style a little bit had given him more yield from his Swarna-Sub1.

"Seven and a half tons," he said happily. "I was able to harvest 7.5 tons per hectare from my Swarna-Sub1.

"Learning about better seedbed management and proper use of NPK dosage has helped me grow healthy and robust seedlings," said Mr. Swain as he explained why he harvested a bumper crop that year. "My crop grew properly; the grains were heavy."

Speaking for his fellow farmers in the community, he said that, they would continue to grow Swarna-Sub1 and would continue to practice what they've learned from the project team on how to raise healthy seedlings of flood-tolerant varieties.

Partnerships that work

"This is just one of the interventions among many," said Corinta Guerta, the director for external relations at IRRI. "The plan is to develop suitable crop management options for climate-smart rice and exploit their maximum potential under stress conditions. And, we are doing it with the farmers at the center of the seed production and delivery system.

"We are able to accomplish these because of IRRI's strong relationship with donors such as the EC through IFAD that started in 1978," she added. "It is a relationship that has a common denominator of helping Asia's poorest farmers."

"As we worked with the farmers through this project, we came to understand more what their needs are in stress-prone environments and the technologies that were developed are tailor-made for their specific needs," said Dr. Singh.

"Through this project alone, a total of 14.6 tons of seeds of climate-smart rice varieties were distributed directly to 3,340 farmers," said Dr. Singh. But, it did not end there. The beauty of the project is that it is more than just giving seeds to farmers—included with the seed mini-kits are illustrated brochures to introduce technologies on how to cultivate climate-smart rice.

And, under the IRRI-led Global Rice Science Partnership (GRiSP), several farmer training activities were organized through collaborations with projects such as STRASA, EC-IFAD, IRRI, and India's National Food Security Mission (IRRI-NFSM), among others, in which many senior technical experts from national agricultural research and extension systems (NARES), NGOs, and IRRI delivered lectures on various management aspects of climate-smart rice.

"More importantly, the knowledge gained from this project is also shared with other project teams with similar goals of helping the smallholder farmers in rainfed South Asia," Dr. Singh said. "As a result, our NARES partners and local communities have more access to relevant information and suitable technologies."

Ms. Reyes is the managing editor of Rice Today.

Rice facts

The global rice market winks at *El Niño* and Thai problems

by **Samarendu Mohanty**

The global rice market has been quite uneventful in the past several months. The news of possible monsoon failure in India and Southeast Asia because of *El Niño*, the uncertainties involving the Thai rice-pledging scheme, and the fate of existing rice stocks have failed to perturb the market.

The only exceptional event in the market has been the steady downward slide of Thai rice prices because of uncertainties in the pledging scheme. Between February 2013 and May 2014, the Thai price for 25% broken rice declined by more than 40% from US$584 to $346 per ton (Fig. 1). During the same period, the large spread of $150–200 per ton between Thai and competitor prices (India, Vietnam, and Pakistan) more or less disappeared, and, in some cases, the Thai price fell below some competitor prices.

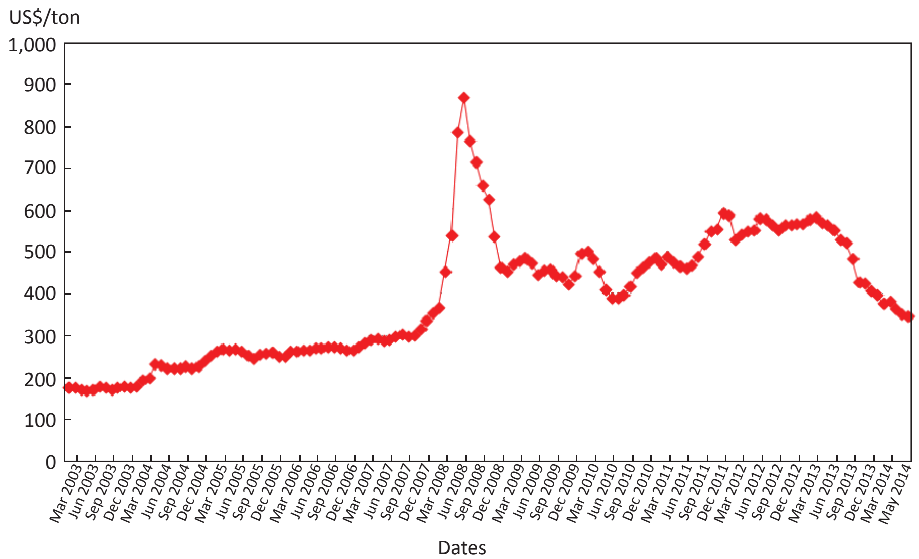


Fig. 1. Thai 25% broken rice price.
Source: FAO Rice Market Monitor and Pink Sheet, World Bank.

This has enabled Thailand to export more in the international market. During the first four months of 2014, Thai rice exports increased to 2.93 million tons compared with 1.98 million tons during the same time a year ago.[1]

The failure of the Thai government to raise funds for the pledging scheme to continue because of political turmoil and the caretaker status of the government led to the steep decline in Thai rice prices in the past several months. In addition, the government has been auctioning rice from existing stocks to raise funds to pay off farmers who pledged rice late last year, putting further downward pressure on Thai prices.

Although the current military junta in Thailand is concerned about the low rice prices for farmers, it is not clear what measures it will implement to raise these prices. The government has also not spelled out its plan on how its existing stocks will be released to the market. We hope that the current government will not repeat the mistake made by its predecessor and will find a nondistorting way to support farm income if it desires to do so and let the market work. If this happens, Thai rice exports will rise and, undoubtedly, the country will become the top exporter again.

Apart from political uncertainties in Thailand, the rice market also faces weather uncertainties in the coming months because of El Niño. Many rice-growing countries in South and Southeast Asia are cautiously optimistic on rainfall distribution in the next few months that will determine the fate of the biggest crop of the year.

In the case of India, the largest rice exporter in the world, where the wet-season crop accounts for more than 85% of the total crop, the southwest monsoon arrived in Kerala on 6 June, after missing its date with the country by 5 days. Some uncertainties exist on how quickly it will spread to the rest of the country. Earlier this season, forecasters had predicted the monsoon rainfall in India this year to be 95% of the long-term average, with an error of ±5%. Apart from India, two Southeast Asian rice importers, Indonesia and the Philippines, are also bracing for weather disruptions from El Niño.

Where is the market going?

This all depends on the fury of El Niño. If the drought is severe in large parts of South and Southeast Asia, it will put pressure on rice prices despite adequate global rice stocks right now. We are undoubtedly in a much better position with a global stocks-to-use ratio of 23.5% now compared with 18.5% in 2007 (Fig. 2). The stocks have increased by 36 million tons from 75

[1] *Source: Thai Rice Exporters Association, accessed on 8 June 2014.*

million tons in 2007 to 111 million tons in 2014 (Production, Supply, and Distribution Online, USDA).

But the bad news is that almost all the increases in these rice stocks (Fig. 3) are primarily with India, China, and Thailand—and a majority of them are in government warehouses rather than with private traders. In case of a crisis or production shortfalls, this may create panic among rice-importing countries as they will be unsure whether these government-held stocks will be available for sale and at what price.

In the case of India, the new government was just sworn in a few weeks ago and it is not clear how it will react to any significant production shortfall caused by weather disruptions. As of 16 June 2014, the monsoon season was already 10 days behind in a majority of the rice-growing belts in the country. The new government is already jittery about the poor prospects of monsoon crops, particularly rice. Although the current government rice stock of 28 million tons (as of 1 June 2014) is at a quite adequate level, it has declined by 4 million tons from 32 million tons at the same time last year.[2] The new government will be under pressure if planting is substantially delayed because of the late onset of monsoon and it may take measures to restrict exports, at least for nonbasmati rice, to safeguard its domestic food supply and keep enough in its warehouses to meet the need of the National Food Security Act (see *India makes access to food a right, not a privilege* on page 43 of *Rice Today*, Vol. 13, No.2).

In the case of Thailand, it is becoming more evident that its rice-pledging scheme will not come back. Without it, it is a no-brainer that Thai farmers will plant less rice in the wet season. But, that should not be a problem for the global market because Thailand has plenty of stocks to make up for the shortfall.

Indonesia and the Philippines, two major rice importers in Southeast Asia, are also expected to be affected by El Niño. As of April 2014, the Philippines had a rice stock of 2.18 million tons, sufficient for 64 days of domestic consumption. Similarly, Indonesia has 6.8 million tons of rice stock to meet its domestic consumption for 62 days. So, any significant weather disruptions will push these countries to import more, thus raising global rice prices. China, the largest importer of rice in the world, is also expected to be affected by El Niño in the form of heavy rains and flooding in the major rice-growing parts of the country. If the rice crop is affected and the domestic rice price goes up, Chinese traders will have more reasons to import more rice than what market pundits have predicted.

Overall, the market is well positioned to handle a moderate drought and other incidences of extreme weather. Thai rice stocks will come in handy to keep the market stable to some extent, but significant weather disruptions in key rice-growing countries will eventually move prices higher. We hope that countries will not repeat the mistakes they made in 2007 by imposing an export ban and stockpiling in anticipation of shortage. Otherwise, we might be heading for another crisis.

Dr. Mohanty is head of the Social Sciences Division at the International Rice Research Institute.

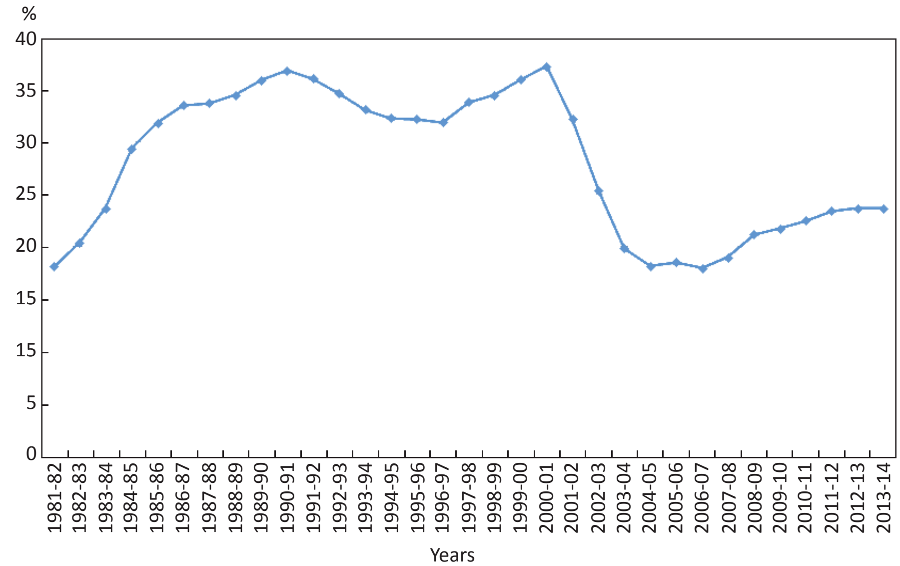


Fig. 2. Global rice stock-to-use ratio.
Source: PSD, USDA.

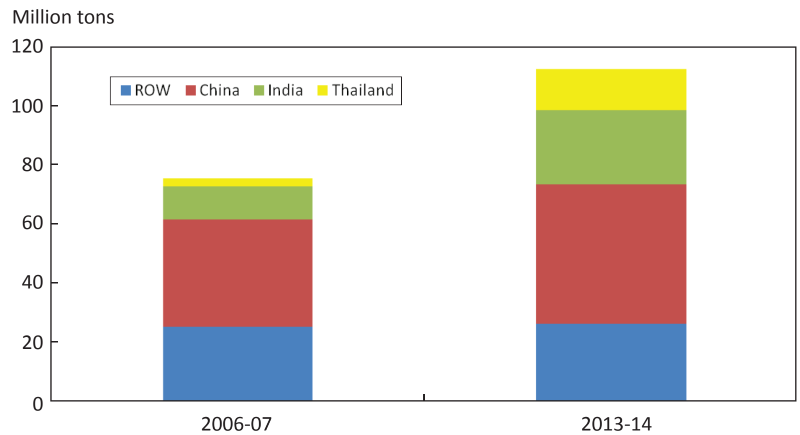


Fig. 3. Global rice ending stocks.
Source: PSD, USDA. *ROW: rest of the world.

[2] *Food Corporation of India website, accessed on 9 June 2014.*

The two faces of rice prices

by **David Dawe**

International and domestic prices are moving in different directions, thus creating two different effects on farmers and consumers

In the wake of the world food price crisis of 2007-08, the consensus view is that, because of several trends (climate change, biofuels, scarcity of land and water, increased consumption of meat), we are entering a new era in which food prices will be higher. How has this played out so far in the case of rice?

Cheaper on the world market

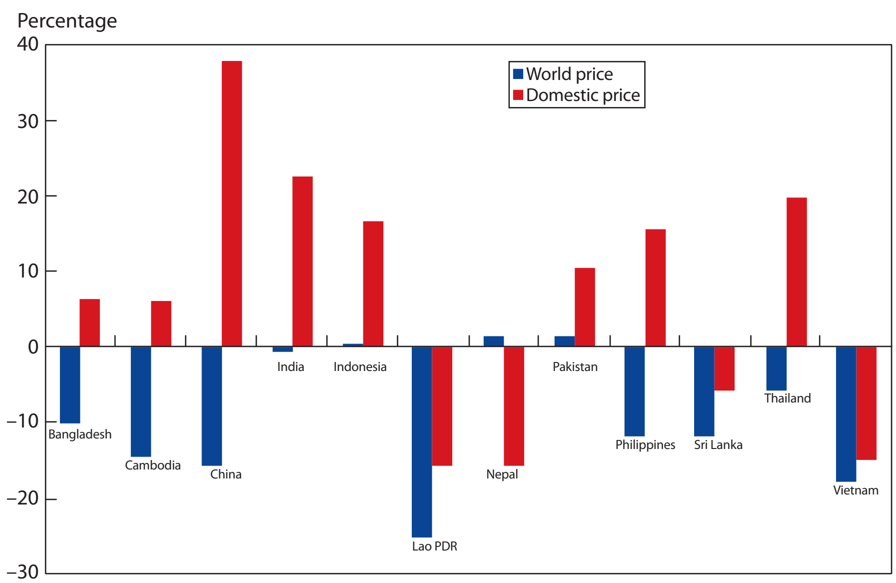
Certainly, world market rice prices have increased. The price of Thai 5% broken milled rice was 56% higher in 2013 than in 2007. But, this is misleading because, after adjusting for inflation, the price of Thai 5% broken rice increased by just 39% during that time. More importantly, Thailand is no longer the center of the world rice market, and prices from other sources have increased by much less. In real terms, the price of Vietnamese 5% broken rice increased by just 11% over the same interval, and the prices of 25% broken rice from India and Pakistan increased by 24% and 14%, respectively.

But even these numbers overstate the extent of effective changes in world prices, because the currencies of most Asian countries appreciated in real terms vis-à-vis the U.S. dollar by 10–20% during this time, thus mitigating the extent of the world price increase. When real exchange rates appreciate, that means it is cheaper to buy products on the world market in local currency. Thus, for all large Asian developing countries, the opportunity cost of Vietnamese rice in real local currency terms in 2013 (i.e., after adjusting for inflation and real exchange rate appreciation) was about equal to or lower than it was in 2007 before the crisis.

Simply put, this means that, for those who need to purchase it, rice was cheaper in 2013 than it was before the crisis in 2007. And, world market prices have fallen even further in the first few months of 2014.

Higher domestic prices

Despite the constant or lower opportunity cost of rice on the world market, domestic rice prices increased in real terms in these same countries from 2007 to 2013 (see figure). One of the key recent developments in the Asian rice economy has been the increase in buying prices paid to farmers in some countries. This trend has been particularly pronounced in Thailand and China, where buying prices paid to farmers have increased by 92% and 59%, respectively, over the past 6 years. In contrast, buying prices in India have increased by 17%, while in Bangladesh they have increased by only a modest 6% (all changes are in local currency terms, adjusted for inflation). In both Thailand and China, broader



Percentage changes in world and domestic prices, inflation-adjusted local currency terms, 2007-13.
Source: National statistical agencies, International Monetary Fund.

measures of domestic rice prices have also increased substantially: comparing 2013 with 2007, wholesale market prices increased by 20% and 38%, respectively, in real terms. These large increases took place although the baht and the yuan have appreciated by more than the world price of Vietnamese 5% broken has increased. In other words, the opportunity cost of rice on the world market has actually declined in real local currency terms for both of these countries.

Why have domestic prices increased so much in these two countries? Both of them have witnessed exceptional economic growth rates over the past few decades, leading to a structural transformation of their economies. At the same time, the share of agriculture in employment remains well above its share in gross domestic product (GDP), meaning that agricultural producers and workers are less productive—and have lower incomes—than those in other sectors of the economy. This economic change is difficult for many people who rely on farming as a key source of income—and add to this the fact that China and Thailand have the highest income inequality in the region. Thus, these countries are raising domestic prices to provide more support to farmers and to reduce inequality, both politically popular. China has also carried out other measures to support farmer income, such as cash transfers and income tax exemptions.

A second key development in recent years has been the push toward self-sufficiency in the wake of the world rice price crisis, especially by Indonesia and the Philippines, which are traditionally the largest importers in the region. These two countries have occasionally lowered their rice imports during the past decade although domestic rice prices have been well above prices on the international market. This push toward self-sufficiency has meant that domestic prices in these countries are rising even higher: rice prices in the Philippines in 2013 were 16% higher than they were in 2007, and 17% higher in Indonesia (both after adjusting for inflation). In Indonesia, local prices in 2013 were 88% higher than the average during 1975-95, when domestic prices were stable around the trend of world prices.

The rising prices in these two countries are partially due to the same factors of structural transformation in China and Thailand, but also because their status as traditional importers makes them more vulnerable to fluctuations on the international rice market—a market that is now viewed as more unstable than in the wake of the food price crisis.

The trends of rising domestic prices are not found everywhere in the region—prices have declined in poor countries such as Vietnam, Lao PDR, and Nepal. Prices have increased, but by small amounts, in other poor countries such as Bangladesh and Cambodia. Because these countries are substantially poorer than the countries discussed above, they are less advanced in the process of structural economic transformation. Their income inequality is also generally lower.

When domestic prices are higher

What are the consequences of higher domestic prices? Higher domestic prices are not generally good for poverty as they harm poor rice consumers (who in countries such as Indonesia and the Philippines are the poorest of the poor). Even in exporting countries such as Thailand, most of the benefits of higher prices end up with the farmers with the most land because benefits accrue only when marketed surplus is sold. Higher rice prices can also raise workers' wages to compensate for the higher food prices, thereby reducing the competitiveness of the industrial sector without benefiting workers. Although higher domestic rice prices may eventually be inevitable, as in Japan and Korea, the rise in domestic prices in some ASEAN countries is probably happening too early in the development process.

These costs are important to note, but political imperatives often dictate that farmers must be supported in some way. In this case, it is important to design programs that transfer the needed financial resources at the lowest possible cost, avoiding excessive losses due to leakage to people who are not poor. It is also desirable to avoid large distortions in resource allocation that delay agricultural diversification. Some types of cash transfer programs, either unconditional or conditional on school attendance, may help in this regard.

What do rising domestic prices mean for the world rice market? As domestic prices increase above world market prices in some countries, farmers are encouraged to produce more rice and consumers to buy less. These added supplies and lower demand mean fewer imports from some countries, and eventually more exports from others (assuming the rice is not allowed to rot in storage). These trends will lead to downward pressure on international prices, possibly negating the consensus view that we are now in a new era of high world rice prices.

Lower world prices in turn will make it harder to continually finance the high domestic farm prices. Many developed countries can afford such subsidies because their agricultural sector is a much smaller share of the economy. They can provide substantial benefits to farmers without undue strain on the government budget. But, the opportunity cost of subsidies is much higher in poor countries, and it is not clear whether such subsidies are sustainable—witness the recent unwinding of the paddy pledging program in Thailand (see more on the Thai situation in the *Rice facts* on pages 38-39). If such subsidies do not continue, the world price, after falling for a time in the near term, will then eventually rise again.

Dr. Dawe is a senior economist in the Agricultural Development Economics Division of the Food and Agriculture Organization of the United Nations.

Yield increase prospects for rice to 2050

BY TONY FISCHER

Rice is the most important staple food for more than half the planet's population, particularly for the poor of Asia. World rice yield, herein called farm yield (FY), is currently increasing constantly at only 1% per year relative to the 2010 global average yield of 4.3 tons per hectare.

To understand yield prospects to 2050, when the number of rice eaters will be more than ever, FY must be disaggregated into the key rice-growing regions and underlying yield drivers. For the latter, we define potential yield (PY) as the yield obtained, usually in breeders' plots grown across the region of interest, with the best-yielding new varieties and without biotic stresses such as diseases and pests, and abiotic stresses such as drought, flooding, salinity, heat, and cold. The PY to FY difference is the yield gap, which is expressed as a percentage of FY. With risk and economics being considered, a minimum yield gap of no less than 30% can be met by the best farmers. FY progress arises from an increase in PY and closure of the yield gap.

For each of the world's seven major rice mega-environments, 13 recent case studies were used to explore FY, PY, and the yield gap over the past 20–30 years. The FY increase was significant in all situations and ranged from 0.2% to 2.2% per year. The current rates for PY progress (and also of water-limited PY, one case) were also all significant, ranging from 0.6% to 1.3% per year, with an average of 0.8%. By difference, the rate of yield gap closing varied from as high as 1.5% per year to -0.6% per year (i.e., widening not closing) for an average closing of 0.4% per year.

The sample average yield gap for rice was 76% but the range was large (25% to 150%) with a smaller gap for irrigated rice (57%) than for rainfed rice (123%). These results show that it is important to continually lift PY for future FY progress, especially with irrigated rice, which contributes to about 80% of world production. The results also point to the generally slow rates of yield gap closing, but gap closing cannot be neglected as it often targets the poorest producers.

Yield gaps in rice are inevitably due to many agronomic constraints, poor farmer knowledge, and weak rural infrastructure and institutions. Some constraints can be alleviated with targeted agronomic research and breeding for better stress resistance, which is beginning to show promise and is also likely to benefit from genetic engineering (GE).

In Brazil's irrigated rice region, yield gap closing is impressive (1.3% per year) because farmers, and the public and private sectors are highly involved in technology transfer. Similar concerted efforts, which target all players and are accompanied by rural development, will likely deliver substantial yield gap closing. However, the shrinking size of Asian rice farms and their weak human resource base pose a special challenge.

Lifting the rate of PY progress will be more difficult, as the harvest index is above 0.5 in the best materials around the world and is unlikely to increase much more. Studies in Japan suggest that recent breeding progress in PY has increased leaf photosynthetic rate around panicle emergence, and there may be scope to further exploit natural variation in photosynthetic traits as rice genetic resources are explored. We don't expect GE (e.g., C_4 rice) to lift PY at least for several decades. Hybrid rice from tropical areas will likely give a one-off boost to PY by 10–20% over the next decade or so. And this has not been considered in the rate of PY progress.

To 2050, any negative effects arising from temperature rise driven by climate change are likely to be balanced by the benefit of rising CO_2 for crop photosynthesis. The substantial global warming effect of methane from paddy rice and the inefficiencies in water and nitrogen use and the tendency for pesticide overuse in rice cropping are weaknesses to be overcome. This will need substantial research and much improved crop management if rice production is to be sustainably intensified globally. However, the greatest potential environmental impact arises from further land clearing for any type of cropping.

Lifting rice FY progress to more than 1% per year will likely be needed to eliminate direct or indirect pressure for land clearing for rice. But, this will be difficult and will require more substantial investment in R&D and in rural development generally.

Dr. Fischer, a former member of IRRI's Board of Trustees (2005-10), is an honorary research fellow at Australia's Commonwealth Scientific and Industrial Research Organisation. More details on yields for rice and a host of other important crops can be found in his just-released book (see page 9).

What's cooking?

by **Inez Slamet-Loedin**

Nasi kuning (yellow rice) is a traditional Indonesian rice dish cooked with coconut milk and turmeric that is usually eaten during special events. The yellow color of the dish is said to resemble gold, so it is often served during special occasions to symbolize good fortune and wealth. It is usually served with a variety of side dishes such as satay. Satay is a dish of chicken, goat, mutton, beef, pork, fish, or other meats, diced or sliced, seasoned, skewered, and grilled, and then served with various spicy seasonings.

ISAGANI SERRANO (2)

Nasi kuning and chicken satay

Nasi kuning

Ingredients

3 cups rice
1/2 inch fresh turmeric (grated)
1 cup coconut milk
1 teaspoon lemon juice
1 tablespoon ground coriander seeds
Salt

Directions

Wash the rice once. Mix the coconut milk, turmeric, and coriander and then add to the rice. Put lemon juice in the rice to give it a nice yellow color and add a little salt. Cook in a rice cooker.

Chicken satay

Ingredients

1/2 to 3/4 kilograms chicken thighs (cut into long strips)
½ cup peanuts
5 pieces garlic
5 pieces candlenuts or pili nuts
2 tablespoons margarine (melted)
1 tablespoon coriander
3/4 tablespoon sweet soy sauce
Cooking oil
Salt
Pepper
Chili (optional)

Directions

Satay marinade

Crush the candlenuts or pili nuts and garlic using a crusher or traditional grinder. Crushing the ingredients gives a better aroma. Mix salt, coriander, pepper, and chili (optional) with the crushed nuts and garlic.

Fry the mixture using peanut, olive, or any kind of oil in a pan until the mixture turns light brown.

Add the peanuts, melted margarine, and sweet soy sauce.

Chicken satay

Marinate the chicken in the sauce for at least 30 minutes. Grill in the oven or barbeque until well done.

Satay sauce

Add water and more sweet soy sauce to the leftover marinade. Bring to a boil and serve with the chicken.

Dr. Slamet-Loedin is a molecular biologist and heads the Genetic Transformation Laboratory at the International Rice Research Institute (IRRI). Her work at IRRI aims at helping two billion women and children who are affected by micronutrient deficiency, also known as "hidden hunger." She leads a team that develops healthier rice, particularly iron- and zinc-rich rice.

When she is not in the laboratory, she is busy in the kitchen— whipping up some dishes for her family, who now stays with her in the Philippines. Although she enjoys some Filipino dishes, she finds time to cook Indonesian dishes to let her family experience the "taste of their home country."

Watch Dr. Slamet-Loedin demonstrate how to prepare this delicious Indonesian dish in a 7-minute video on http://youtu.be/i1_Qe6hGf8Q.