Bread and Brain, Education and Poverty
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www.pas.va/content/dam/accademia/pdf/sv125/sv125-zeigler.pdf

The Quest to Assure a Well-Fed World in 2050 Will Take an Integrated Global Effort[1]

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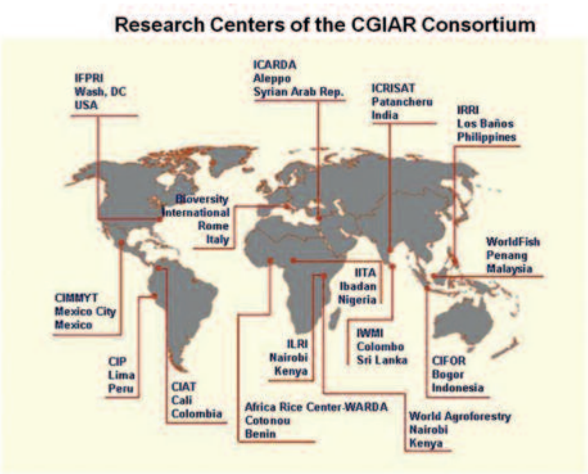
It is my privilege to be a member of this distinguished Working Group formed by the Pontifical Academy of Sciences to examine the present state of malnutrition, brain development, and education problems, and to help identify a set of actions.

Our greatest challenge: producing more food to feed the world

As the global population continues to grow toward a predicted nine billion souls by 2050, I believe it will be humanity's greatest challenge to produce more food to feed the world 37 years hence without wrecking the planet. This is in the face of food production systems that are rapidly chang-



[1] Based on a presentation made at a meeting of the Working Group on Bread and Brain, Education and Poverty 5 November 2013, The Pontifical Academy of Sciences, Vatican City.

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ing, climate variability that is making the poor even more vulnerable, and urbanization that is drastically altering the agricultural landscape.

To alleviate poverty and malnutrition – the main concerns of this workshop – and to ensure food security for everyone, it will be essential to conduct targeted research with an aim to empower poor rural communities and raise the productivity of staple crops and agricultural systems, which include livestock, fish, and agroforestry. I maintain that a science-based second Green Revolution involving an integrated global effort will be required to ental task.

Enter CGIAR, a global partnership that has united organizations – one of those being the International Rice Research Institute (IRRI) – engaged in research for a food-secure future. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources – all through targeted innovation. This urgent work is carried out by IRRI and 15 other centers of excellence and focus that are members of the CGIAR Consortium (see map), in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector. The 15 research centers are currently generating and disseminating knowledge, technologies, and policies for agricultural development through 16 CGIAR Research Programs (CRPs) that range from the staple cereals (rice, wheat, and maize) to other important crops (roots, tubers, bananas, and grain legumes), from livestock and fish to forests and trees, and from nutrition and health to policies and markets.

Unfortunately, time and space will not allow me to provide details on all 16 of these vital CRPs. However, an excellent example is the very first CRP launched by the CGIAR Consortium Board on 10 November 2010, the Global Rice Science Partnership (GRiSP). This is not to mention the facts that rice is my area of expertise as director general of IRRI and that, if we want to do something about poverty, it is clear that we must invest in rice.

GRiSP is a sustained integrated effort to bring together the work of IRRI and the Japan International Research Center for Agricultural Sciences (JIRCAS) in Asia, the Africa Rice Center in Africa, and the International Center for Tropical Agriculture (CIAT) in Latin America into one global and comprehensive rice research program. Other major partners are

Box: GRiSP Research & Development Themes

- **Theme 1:** Harnessing genetic diversity to chart new productivity, quality, and health horizons
- **Theme 2:** Accelerating the development, delivery, and adoption of improved rice germplasm
- **Theme 3:** Ecological and sustainable management of rice-based production systems
- **Theme 4:** Extracting more value from rice harvests through improved quality, processing, and market systems and new products
- **Theme 5**: Technology evaluations, targeting and policy options for enhanced impact
- **Theme 6:** Supporting the growth of the global rice sector

the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and the Institut de Recherche pour le Développement (IRD). If we are successful in developing this CRP and having it reach the level of maturity that we hope it will, it could indeed be transformative in the future of global rice supplies.

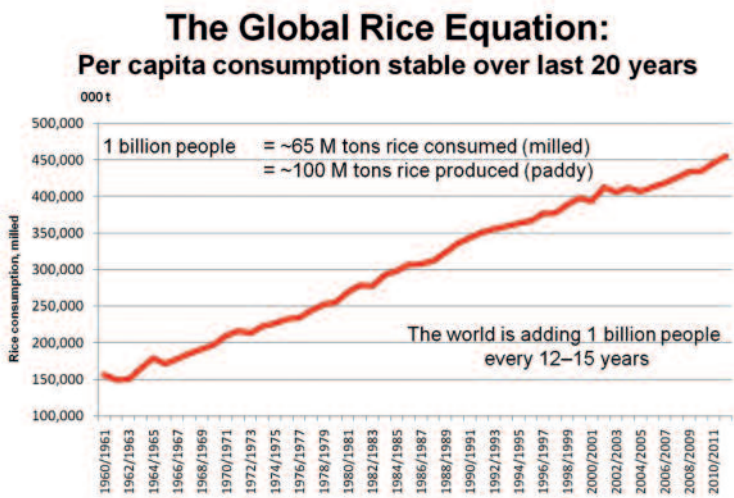
The proactive innovation of GRiSP involves

- A first phase work and business plan (2011–15; extended through 2016);
- Interdisciplinary, product-oriented R&D: 94 products currently clustered in 26 product lines under six themes (see box);
- New frontiers research; and
- Science capacity building.

Poverty is where rice is grown

Now, I'll provide a few more details on why investment in GRiSP – now and in future phases beyond 2016 – is so important, especially in addressing the concerns of this workshop. The map shows where rice is consumed in the world. In large parts of the world, people are eating 70, 80, or 100 kilos or more annually (shades of green). Where rice is widely consumed, each red dot on the map represents 250,000 people living on less than US$1.25 per day – abject poverty. The world today still has huge concentrations of poverty and most of these concentrations are where rice is grown. This is the message I try to make clear to anyone who will listen – if we want to overcome problems of poverty and hunger, rice must be part of the solution!

Now, if we look at the global rice equation, as far as we can tell, the demand for rice is going to continue to grow for many decades to come. Every prediction that the demand for rice is going to taper off has proven to be incorrect. If we look at the population trends for the next several decades, the world is going to be adding about a billion people every 12 to 15 years. Now, a billion people translate into 100 million tons of additional



paddy to feed them. So, just in order to keep pace with population growth, we'll have to add 100 million tons of paddy (produced rice) or 65 million tons of milled rice every decade and a half – a major challenge!

One key question is: Where will the world's rice come from in the future? Ideally, it will come from existing lands, primarily in Asia. We don't want to be clearing new land for agriculture. We want to make existing land more efficient. But, if we consider the social and economic dynamics across Asia and indeed the rest of the world, land is moving out of agriculture.

More challenges for GRiSP

In order to meet the needs of the future, GRiSP is going to have to come up with huge innovations in production practices, which must be driven by research, just to stay where we are – if you revisit that poverty map. However, "just where we are" is simply not good enough!

Climate change

So, the challenges that face the GRiSP partners on three continents are enormous. Just consider the world climate change that we got a sample of all around us in 2013 with particularly vicious storms in the Philippines and elsewhere and too much water in some regions while there was not enough precious moisture in others. Temperatures are increasing. CO_2 levels in the atmosphere are increasing. Rainfall patterns are shifting. Sea levels are rising (more on that in a moment). Weather hazards combined with rising sea levels will put the high population concentrations inherent near the coasts in ever-increasing danger. These are all facts.

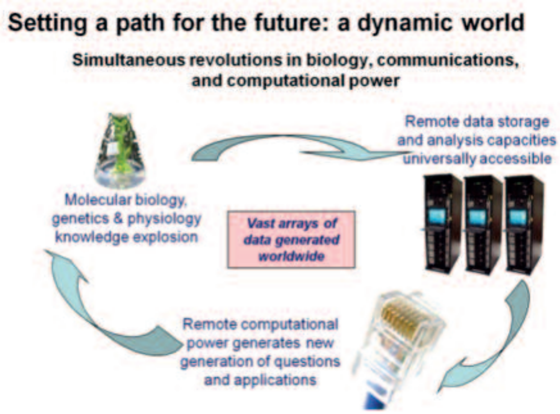
We face a situation in which the challenges brought on by climate change are going to affect agriculture, especially rice cultivation. We know that, in the future, we're going to have to have rice varieties that will tolerate higher temperatures and withstand floods. Rice likes to grow ankle-deep in water. However, if you put it completely under water, it will drown. We will also need rice varieties that will tolerate drought and saline soils, particularly along coastal areas. We're going to have to have production practices that are far more efficient, that will demand less water, but that still get a very good yield. We will need to use fertilizers much more efficiently.

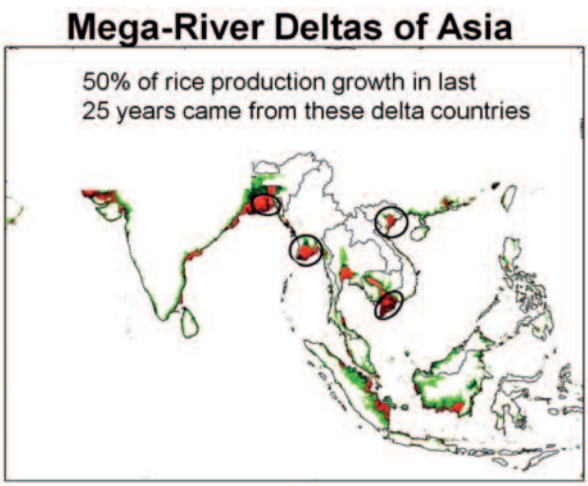
Since many people are moving out of farming, labor will have to be more efficient. So, with less available labor, we're going to have to grow rice far more efficiently using much more sophisticated tools. We can't have those who couldn't make it to be a doctor or a lawyer being our future rice farmers.

A convergence of revolutions

Basically, we're going to have to get sustainably high yields and productivity in ways that are not business as usual. As the illustration to the right, which I put together 10 years ago, still shows, we have had one simultaneous convergence of major revolutions in communications, in molecular biology, in genetics, and in computational power. All of these events by themselves would be revolutionary enough. But combined, they have transformed the way our world is. And no transformation is greater than that in the biological and agricultural sciences.

The GRiSP partners can now address challenges, in terms of understanding genetics, in ways that we could never have dreamed of before. I think





that this is best expressed in the area of genetic resources. IRRI's International Rice Genebank has the world's largest collection of rice germplasm – more than 117,000 rice accessions and wild relatives. Most people probably don't realize that a very tiny percentage of these materials has been used in global breeding programs. We are now just scratching the surface. Those other revolutions in molecular biology and genetics will now enable us to tap into that incredible wealth – thousands of years of farmer knowledge and selection – from very diverse environments. Now, we can really begin to exploit the genetic diversity of rice to meet our future challenges.

Sea-level rise

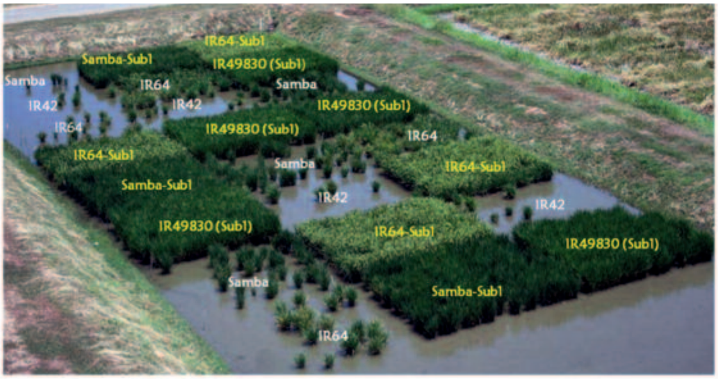
Back to sea-level rise, a major challenge that we have to deal with. The map provides a graphic representation of what we are up against. It shows the river deltas across Asia, which are threatened. The major food supplies of the world come out of these deltas. Research shows that 50% of rice production growth, which we enjoyed over the last quarter century has come from these delta countries. Now, sea-level rise is threatening these areas and, if they all drop off the map in terms of rice production capacity, the world is going to have a major food security crisis. It's up to us to see that this doesn't happen.

Flood- and drought-tolerant rice.

One area that will have great impact is the work we're doing to develop stress-tolerant rice varieties. Already, more than 10 million hectares per year of rice are lost to catastrophic flooding. Even in favorable areas, there are losses to occasional floods. So, just to meet the challenges of today, not to mention what we see coming in the future, some flood-tolerant rice would make a great contribution.

Over the years, IRRI scientists and partners have been working on flood-tolerant rice. A couple of decades ago, they identified a flood-tolerant variety from India, called FR13A (FR stands for flood resistance). If you put this variety under water for 10 days or so, it will recover after the floodwaters recede. The only problem is its terrible grain quality. So, you might produce a variety that can yield under stress, but people still have to want to eat it. And, if it also has poor agronomic traits and it is crossed with other varieties, a breeder's worst nightmare could ensue!

It wasn't until the application of the new molecular tools at IRRI and with U.S. colleagues that breeders were able to move the *FR13A* gene for flood tolerance into commercially acceptable varieties that farmers would be willing to grow – and want to grow.



New Sub1 lines after 17 days of submergence in the field at IRRI. The genes for submergence tolerance have been moved into popular "mega-varieties."

The photo here just can't be beat. It shows the same varieties labeled in white and yellow. The white ones don't have the flood-tolerance gene; the yellow ones do. After 17 days of submergence, one does not need a statistician to indicate which plants are tolerant of flooding and which ones are not!

Researchers' next step was to develop rice varieties that were both flood tolerant and drought tolerant. And today, we have varieties with combined flood tolerance and drought tolerance. It took 20 years but we now have rice varieties for all seasons!

Results in farmers' fields

The ultimate question is, How do these tolerant varieties perform in farmers' fields? Well, on 31 July 2008 at 1:17 in the afternoon, the top photo on the next page shows Indian farmer Asha Ram Pal standing in his rice field after two successive floods contemplating what to do. His neighbors told him to plow it up because he was not going to get any crop out of that field. Forget it! Well, he didn't plow it up and the bottom photo shows what his field looked like on 31 October.

I later asked Mr. Pal, How did his rice taste? He said he actually didn't know because he ended up selling the entire crop as seed to his neighbors – the same ones who laughed at him and told him to plow up the field in July.

Today, this same germplasm is in the hands of almost 3 million farmers, just in eastern India alone! And, it's also moving out into Bangladesh, Nepal, the Philippines, and elsewhere. Note again that time stamp in the upper photo. I would like to suggest that the Second Green Revolution that I mentioned earlier actually started in rice at 1:17 in the afternoon on 31 July 2008 – the exact time when Mr. Pal decided not to plow up his field.

Greener rice

Additional challenges for the GRiSP partners include reducing the water and environmental footprint of rice production. We are promoting climate-smart farming by scaling up and out what is called alternate wetting and drying (AWD) of rice fields. This simple and safe (for the rice) technique, which involves farmers monitoring the water levels in their fields with a *field water tube,* is already widely adopted across Asia and has the potential to benefit tens of millions of rice-farming families. Further adoption of AWD could free up 100 cubic kilometers of scarce water annually and, at the same time, help reduce methane, a greenhouse gas (GHG) that contributes to global warming, from rice production by from 30 to 70%.

Mr. Asha Ram Pal's rice field, Palia Goa village, Faizabad district, Uttar Pradesh, India.

AWD is helping rice farmers cut down their use of irrigation water by 30% and cope with water scarcity – an adverse effect of climate change – without compromising rice yield. It is cheap and easy to implement, thereby lowering the cost of irrigation, thus helping farmers maintain and improve the economic and environmental sustainability of their source of livelihood and contribution to food security.

GRiSP partners are introducing field-specific nutrient management decision tools to extension workers and farmers and also urging a significant reduction in the use of pesticides. Research has shown that most tropical rice crops under intensification require absolutely no insecticide use. But this is a difficult habit to break among farmers who have routinely used pesticides for the last half-century, particularly in Asia, where pesticide merchants are well organized in selling their wares.

Although pesticide use is indeed a management tool, the practice tends to overshadow all the other technologies that can help farmers. Science and other logical methods cannot compete with the pesticide marketers unless the rules that regulate these chemicals are rigorously enforced by the governments of individual countries. GRiSP can assist in this effort by focusing on designing governing structures in countries with this specific problem such as Myanmar, Thailand, Vietnam, and Indonesia.

On to malnutrition

Now, I move on to a challenge that is of particular interest to the participants of this workshop, that is, malnutrition, especially that caused by micronutrient deficiency. I don't want to steal the thunder of Ingo Potrykus, who will be speaking tomorrow on this topic and the valuable lessons learned from research on Golden Rice, which has been genetically modified to contain beta carotene that is a precursor to vitamin A, a particularly significant micronutrient. However, I do want to emphasize the critical importance of overcoming micronutrient deficiency.

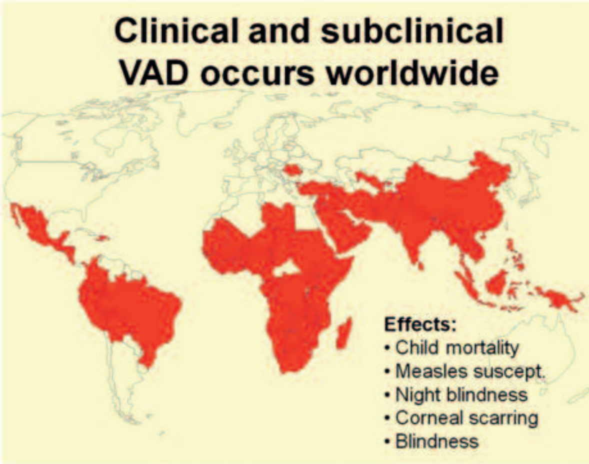
Worldwide, the most seriously limiting nutrient deficiencies in the human diet are iron, zinc, iodine – and vitamin A. Vitamin A is an essential nutrient needed for the visual system, growth, development, and a healthy immune system. Vitamin A deficiency (VAD) is most prevalent among young children and pregnant and nursing women. According to the World Health Organization (WHO), clinical to subclinical severe VAD affects most developing countries (see map).

Despite significant efforts, including capsule supplementation, dietary diversification, fortifying commonly used foods such as cooking oil with vitamin A, and optimal breastfeeding practices, VAD continues to adversely affect an estimated 190 million preschool children and 19 million pregnant women in the developing world. Since rice is widely produced and consumed in poor developing countries, it seems logical that, if this staple could be made to provide a source of vitamin A, it has the potential to reach millions of people who do not have reliable access to or cannot afford other sources of the vitamin.

The nearly 30-year history of the development of Golden Rice is an enlightening story of vision, imagination, technological creativity, and persistence that Dr. Potrykus will elaborate on further tomorrow. Many organizations and individuals in the public and private sector have been involved in this effort that has attracted more than its share of controversy. Recent Chinese studies unequivocally demonstrate that one bowl of Golden Rice (50 grams uncooked, 150 grams cooked) provides 60% of the Recommended Dietary Allowance for children 6 years of age and younger. So, I'm sure we all hope, along with Dr. Potrykus, that Golden Rice's delivery to farmers and consumers will not be delayed much longer by those who oppose the use of this new and promising technology.

Working together globally

As I emphasized at the outset, only a science-based second Green Revolution involving an integrated global effort will allow us to meet the many



challenges involved in feeding the world in 2050. This will require a large portfolio of response options. Certainly, CGIAR, in its current framework involving GRiSP and 15 other far-ranging CRPs (to date) and additional Challenge Programs, is uniquely positioned to carry out many of these options.

Already, CGIAR CRPs accounted for US$673 million or just over 10% of the US$5.1 billion spent on agricultural research for development in 2010. The economic benefits have run to billions of dollars. In Asia, the overall benefits of CGIAR research are estimated at US$10.8 billion a year for rice, US$2.5 billion for wheat, and US$0.8 billion for maize. Political, financial, technological, and environmental changes reverberating around the globe mean that there are many opportunities to rejuvenate the shaky global food system. Developments in agricultural and environmental science, progress in government policies, and advances in our understanding of gender dynamics and nutrition are opening new avenues for producing more food and for making entrenched hunger and poverty a thing of the past. Yes, the future looks bright!

Thank you.

Additional background and information resources

More about CGIAR: www.cgiar.org

More about climate change: http://irri.org/our-work/research/better-rice-varieties/climate-change-ready-rice

More about Golden Rice: http://irri.org/golden-rice

More about GRiSP: www.cgiar.org/our-research/cgiar-research-programs/rice-grisp

GRiSP video on YouTube: http://youtu.be/lCHqB6rLvvk

Scuba rice: stemming the tide in flood-prone South Asia (*Rice Today* magazine): http://fr.scribd.com/doc/94631646/RT-Vol-8-No-2-Scuba-rice

Flood-tolerant rice time lapse on YouTube: http://youtu.be/DJsNwYX1Nc0

Reducing pesticide use in Asia's rice fields: the job is far from finished (*Rice Today* magazine): http://irri.org/rice-today/reducing-pesticide-use-in-asia-s-rice-fields-the-job-is-far-from-finished

Zeigler RS. 2014. Biofortification: Vitamin A deficiency and the case for Golden Rice. In: A. Ricroch, S. Chopra, S. Fleischer, editors. *Plant Biotechnology – Experience and Future Prospects*. Springer (in press).