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September 24, 2014

Rice Science to Ensure Global Nutrition and Food Security

Speaker

Robert Zeigler, *Director of the International Rice Research Institute (IRRI)*

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Upcoming Agrilinks Events:

- Seminar | October 9th | Emergency Seed Systems
- Ag Sector Council | October 22nd | From Smallholders to Shareholders: A Guide to Optimizing Private Sector Partnerships for Smallholder Impact

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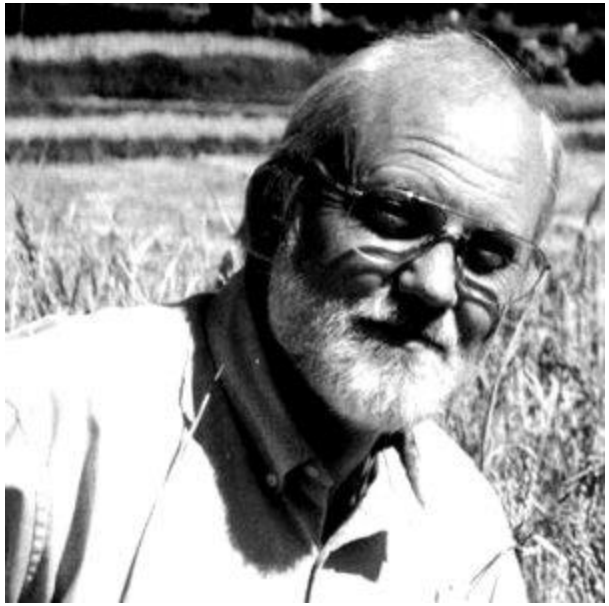
Saharah Moon Chapotin

USAID Bureau for Food Security

Saharah Moon Chapotin is Division Chief for Agricultural Research at USAID. She joined USAID in 2006 as a Biotechnology Advisor, managing international partnerships to promote the adoption of conservation agriculture practices in South Asia, and develop bioengineered crops for small-holder farmers. Prior to working at USAID, Chapotin worked at the Biosafety Institute for Genetically Modified Agricultural Products at Iowa State University. Chapotin holds a B.S. in Biology from Stanford University, a Ph.D. in Plant Physiology from Harvard University, and has completed the AAAS Science and Technology Policy Fellowship Program.



Robert Zeigler

International Rice Research Institute

Robert ”Bob” Zeigler is an internationally respected plant pathologist with more than 30 years of experience in agricultural research in the developing world. He became Director General of the International Rice Research Institute (IRRI) in 2005. IRRI headquarters, with more than 1,000 scientists and support staff, is in the Philippines, with offices in 15 countries and activities in more than 25 others. IRRI focuses on sustaining, understanding, and using the genetic diversity of rice to improve rice productivity and the livelihood of rice farmers and consumers.

IRRI

"Rice Science: A Powerful Weapon in the War Against Hunger and Poverty"

R. S. Zeigler

Director General

International Rice Research Institute

Rice Science for a Better World

INTERNATIONAL RICE RESEARCH INSTITUTE

Los Baños, Philippines
www.irri.org

Mission:

- Reduce poverty and hunger,
- Improve the health of rice farmers and consumers,
- Ensure environmental sustainability
- Through research, partnerships

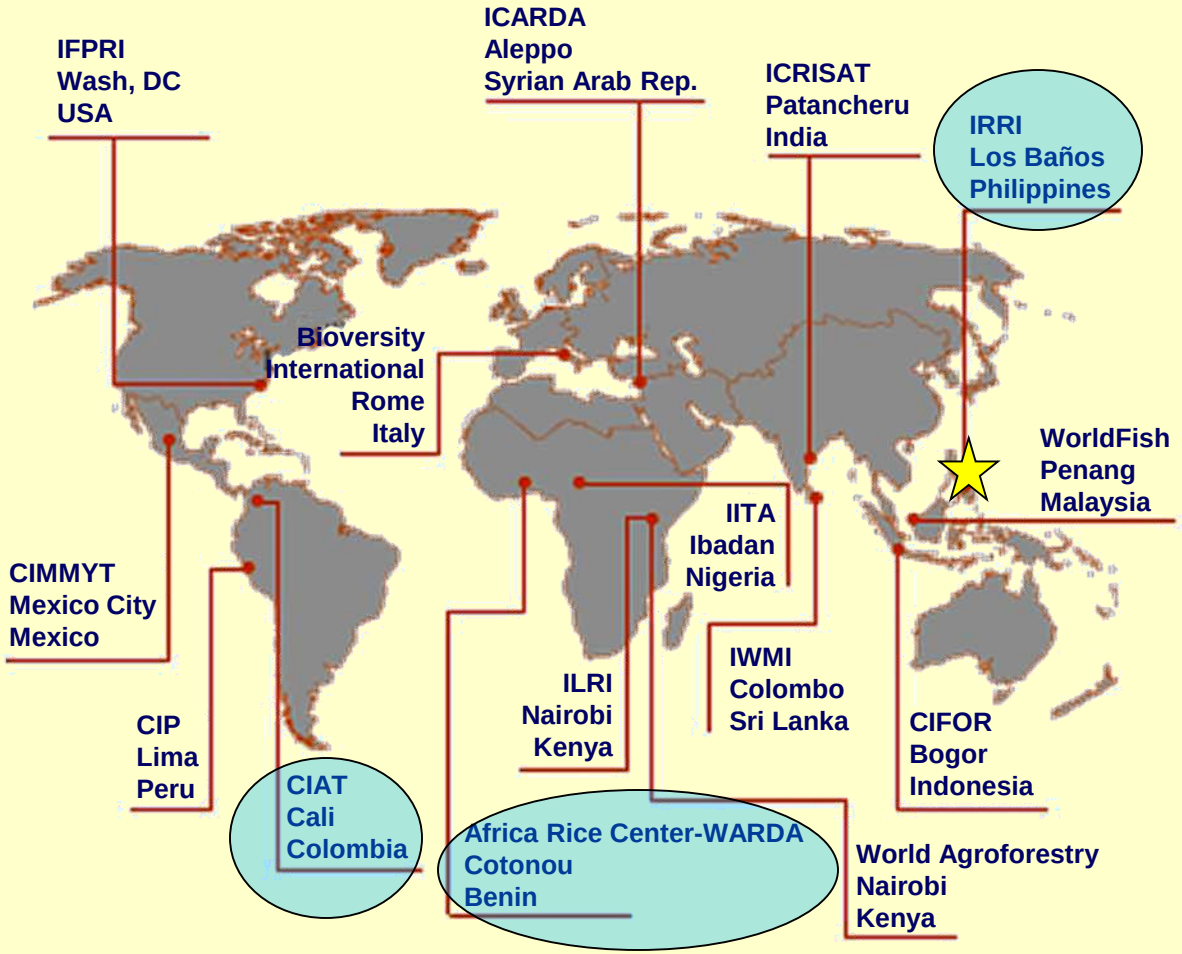
Home of the Green Revolution
Established 1960

A case study in applying research to development

Rice Science for a Better World

Consultative Group on International Agricultural Research (CGIAR)

Global Rice Science Partnership (GRiSP)



Rice Science for a Better World

What is rice?

Perhaps the oldest domesticated crop

- Tremendously diverse

More than just food

- Though it is the primary staple for billions (~ 50% of world & ~ 75% of poor)

Flourishes in an exceedingly wet monsoon environment

- Impossible for other staples

Rice Science for a Better World

Rice is typically grown by small family farm enterprises (<2 ha)…saved seed

Animal draft power

Reliance on human labor…

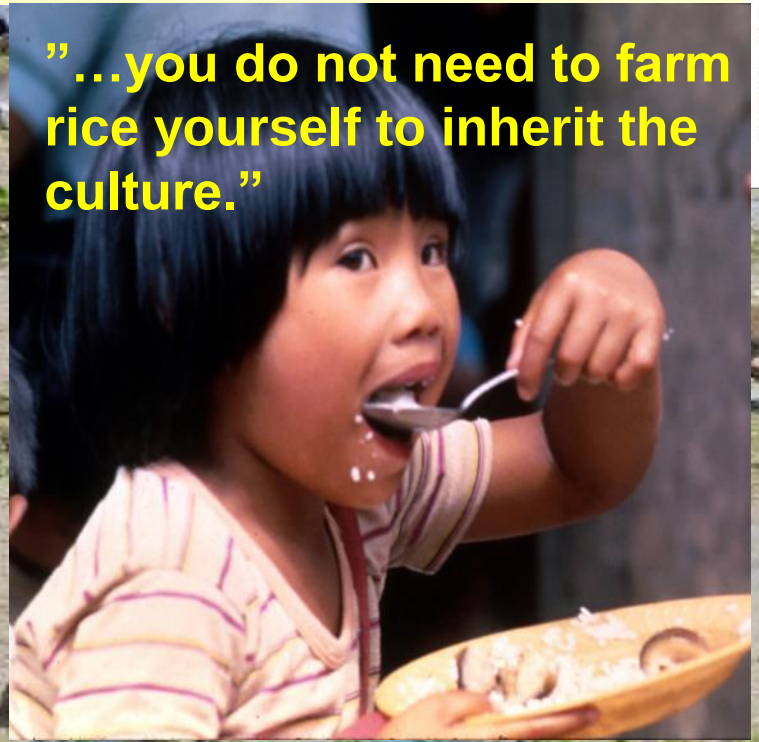
For how long?

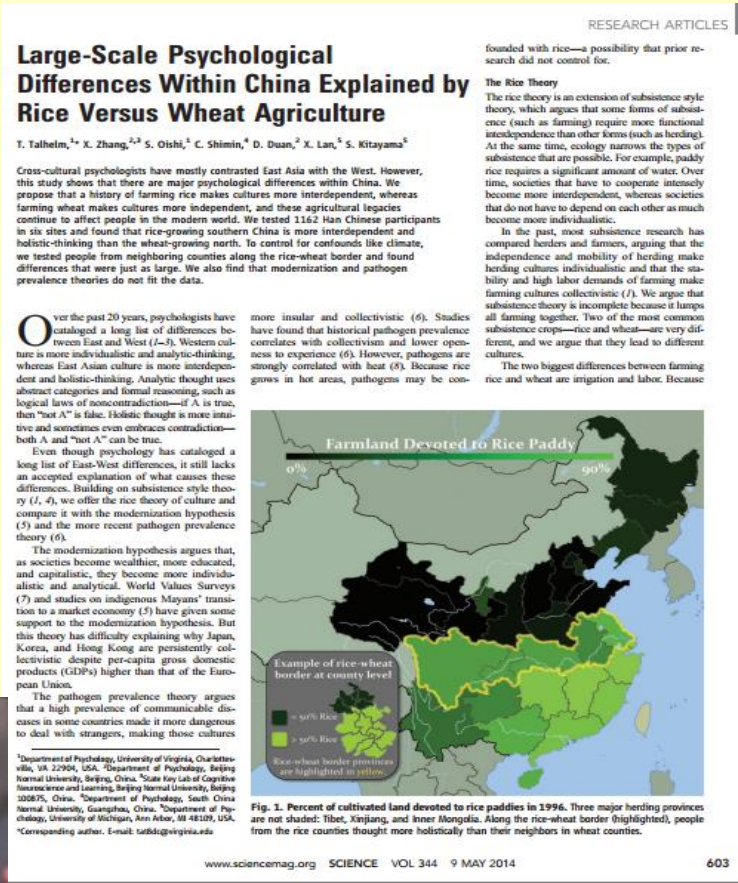
Rice Science for a Better World

The “Rice Theory”

“… proposes that a history of farming rice makes cultures more interdependent, whereas farming wheat makes cultures more independent, and these agricultural legacies continue to affect people in the modern world”

Dr. Thomas Talhelm, University of Virginia





Large-Scale Psychological Differences Within China Explained by Rice Versus Wheat Agriculture

T. Talhelm,[1*] X. Zhang,[2,3] S. Oishi,[1] C. Shimin,[4] D. Duan,[2] X. Lan,[5] S. Kitayama[5]

Cross-cultural psychologists have mostly contrasted East Asia with the West. However, this study shows that there are major psychological differences within China. We propose that a history of farming rice makes cultures more interdependent, whereas farming wheat makes cultures more independent, and these agricultural legacies continue to affect people in the modern world. We tested 1162 Han Chinese participants in six sites and found that rice-growing southern China is more interdependent and holistic-thinking than the wheat-growing north. To control for confounds like climate, we tested people from neighboring counties along the rice-wheat border and found differences that were just as large. We also find that modernization and pathogen prevalence theories do not fit the data.

Over the past 20 years, psychologists have cataloged a long list of differences between East and West (*1–3*). Western culture is more individualistic and analytic-thinking, whereas East Asian culture is more interdependent and holistic-thinking. Analytic thought uses abstract categories and formal reasoning, such as logical laws of noncontradiction—if A is true, then "not A" is false. Holistic thought is more intuitive and sometimes even embraces contradiction—both A and "not A" can be true.

Even though psychology has cataloged a long list of East-West differences, it still lacks an accepted explanation of what causes these differences. Building on subsistence style theory (*1, 4*), we offer the rice theory of culture and compare it with the modernization hypothesis (*5*) and the more recent pathogen prevalence theory (*6*).

The modernization hypothesis argues that, as societies become wealthier, more educated, and capitalistic, they become more individualistic and analytical. World Values Surveys (*7*) and studies on indigenous Mayans' transition to a market economy (*5*) have given some support to the modernization hypothesis. But this theory has difficulty explaining why Japan, Korea, and Hong Kong are persistently collectivistic despite per-capita gross domestic products (GDPs) higher than that of the European Union.

The pathogen prevalence theory argues that a high prevalence of communicable diseases in some countries made it more dangerous to deal with strangers, making those cultures more insular and collectivistic (*6*). Studies have found that historical pathogen prevalence correlates with collectivism and lower openness to experience (*6*). However, pathogens are strongly correlated with heat (*8*). Because rice grows in hot areas, pathogens may be confounded with rice—a possibility that prior research did not control for.

[1]Department of Psychology, University of Virginia, Charlottesville, VA 22904, USA. [2]Department of Psychology, Beijing Normal University, Beijing, China. [3]State Key Lab of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing 100875, China. [4]Department of Psychology, South China Normal University, Guangzhou, China. [5]Department of Psychology, University of Michigan, Ann Arbor, MI 48109, USA. *Corresponding author. E-mail: tatlhdc@virginia.edu

The Rice Theory

The rice theory is an extension of subsistence style theory, which argues that some forms of subsistence (such as farming) require more functional interdependence than other forms (such as herding). At the same time, ecology narrows the types of subsistence that are possible. For example, paddy rice requires a significant amount of water. Over time, societies that have to cooperate intensely become more interdependent, whereas societies that do not have to depend on each other as much become more individualistic.

In the past, most subsistence research has compared herders and farmers, arguing that the independence and mobility of herding make herding cultures individualistic and that the stability and high labor demands of farming make farming cultures collectivistic (*1*). We argue that subsistence theory is incomplete because it lumps all farming together. Two of the most common subsistence crops—rice and wheat—are very different, and we argue that they lead to different cultures.

The two biggest differences between farming rice and wheat are irrigation and labor. Because

Farmland Devoted to Rice Paddy
0%
90%
Example of rice-wheat border at county level
> 90% Rice
> 90% Rice
Rice-wheat border provinces are highlighted in yellow.

Fig. 1. Percent of cultivated land devoted to rice paddies in 1996. Three major herding provinces are not shaded: Tibet, Xinjiang, and Inner Mongolia. Along the rice-wheat border (highlighted), people from the rice counties thought more holistically than their neighbors in wheat counties.

The Green Revolution in Asia

1960s

- *yields ~1.5 t per ha*
- *widespread famines predicted*

Today

- *yields ~4 t per ha*
- *economic growth*

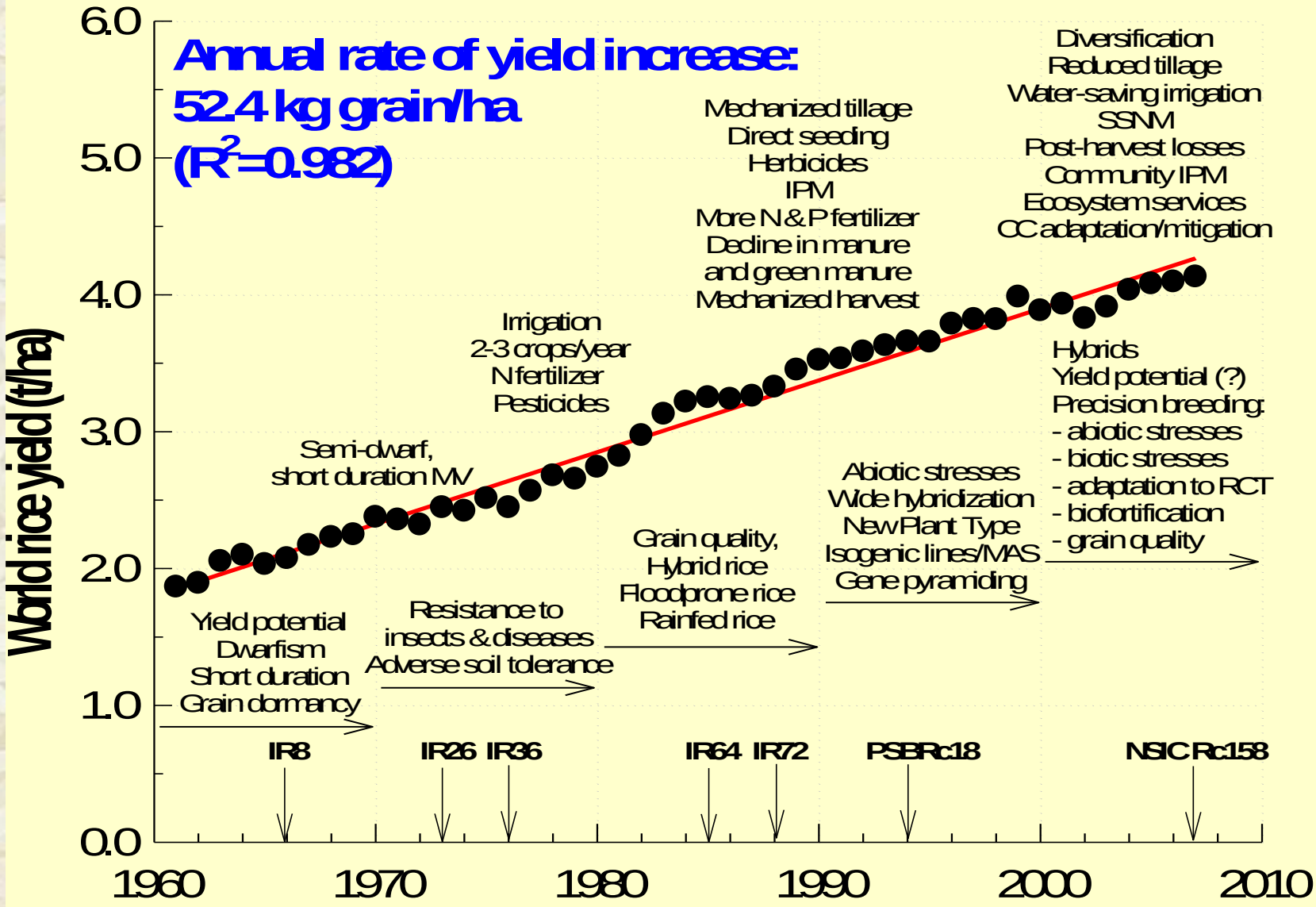
IR8 (semi-dwarf) launched the Green Revolution and saved millions from starvation

Science doing what people said could never be done

Image source: Nature 418, 674-684 (8 August, 2002)

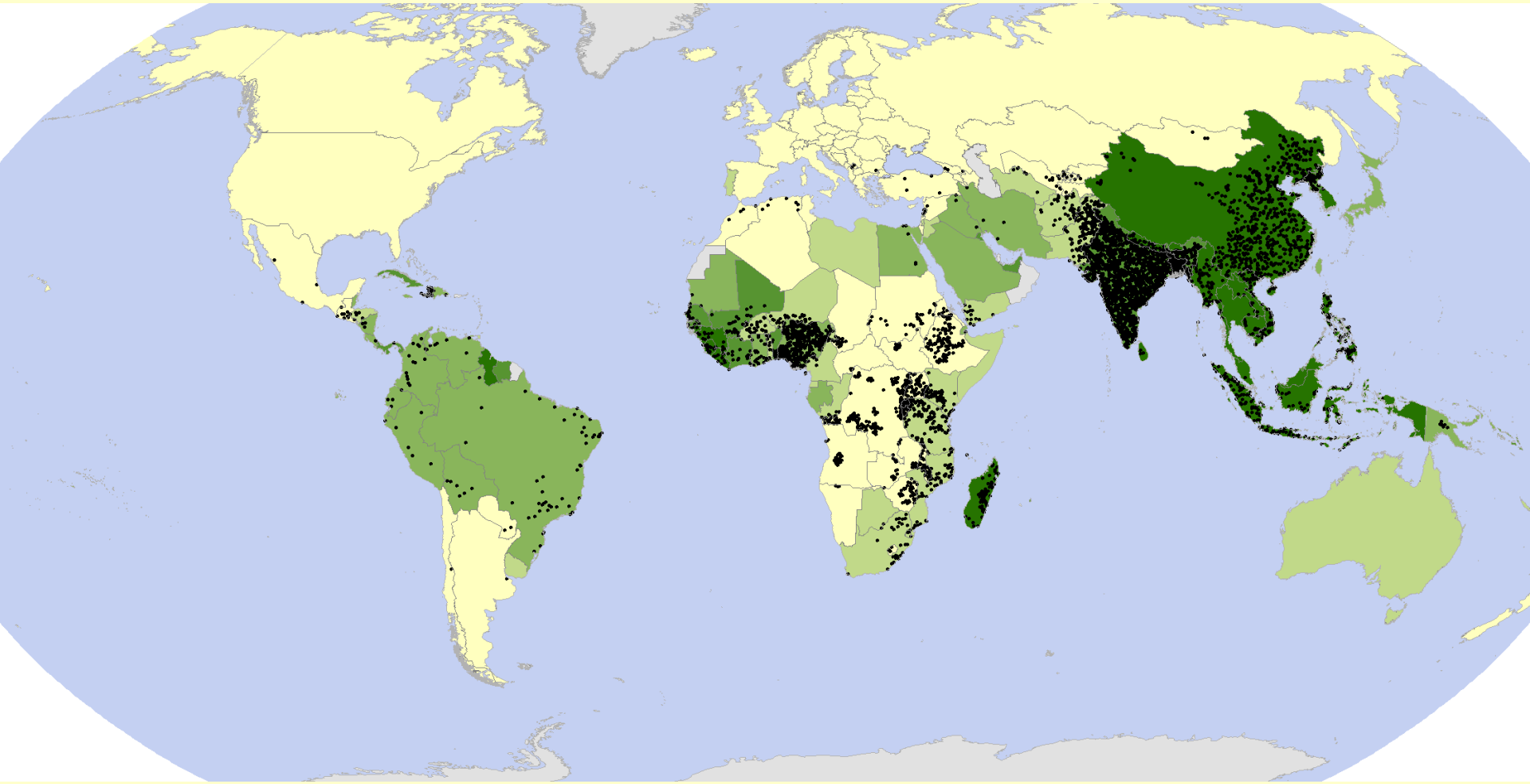
Rice Science for a Better World

IRRI



Rice Science for a Better World

If we want to do something about poverty, it is clear that we must invest in rice



Milled rice consumption (FAO, 2011)

Annual consumption per capita (kg)

<10 10-25 25-50 50-75 >75

Poverty headcount (World Bank)

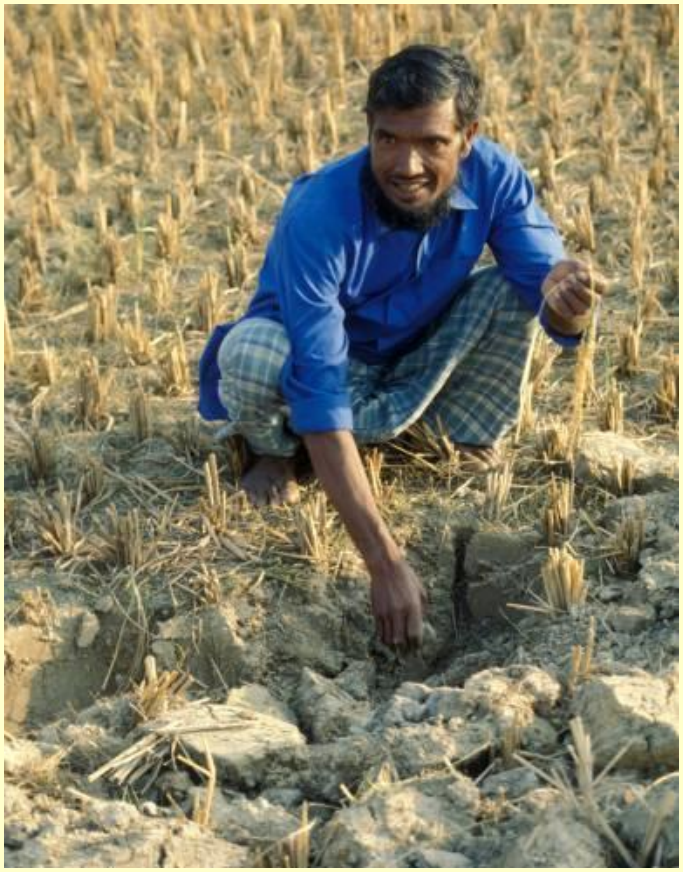
Each dot represents 250,000 people living on $1.25 (PPP) a day or less

1.3 billion people in 2012

Food supply quantity for milled rice from FAOSTAT. Poverty headcount from the most recent survey year in the 2012 World Bank Indicators Database. Poverty distribution based on population density. Boundaries, colours, denominations and other information shown on this map do not imply any judgment on the part of IRRI concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

The face of poverty

The consequences of poverty… Hunger and malnutrition



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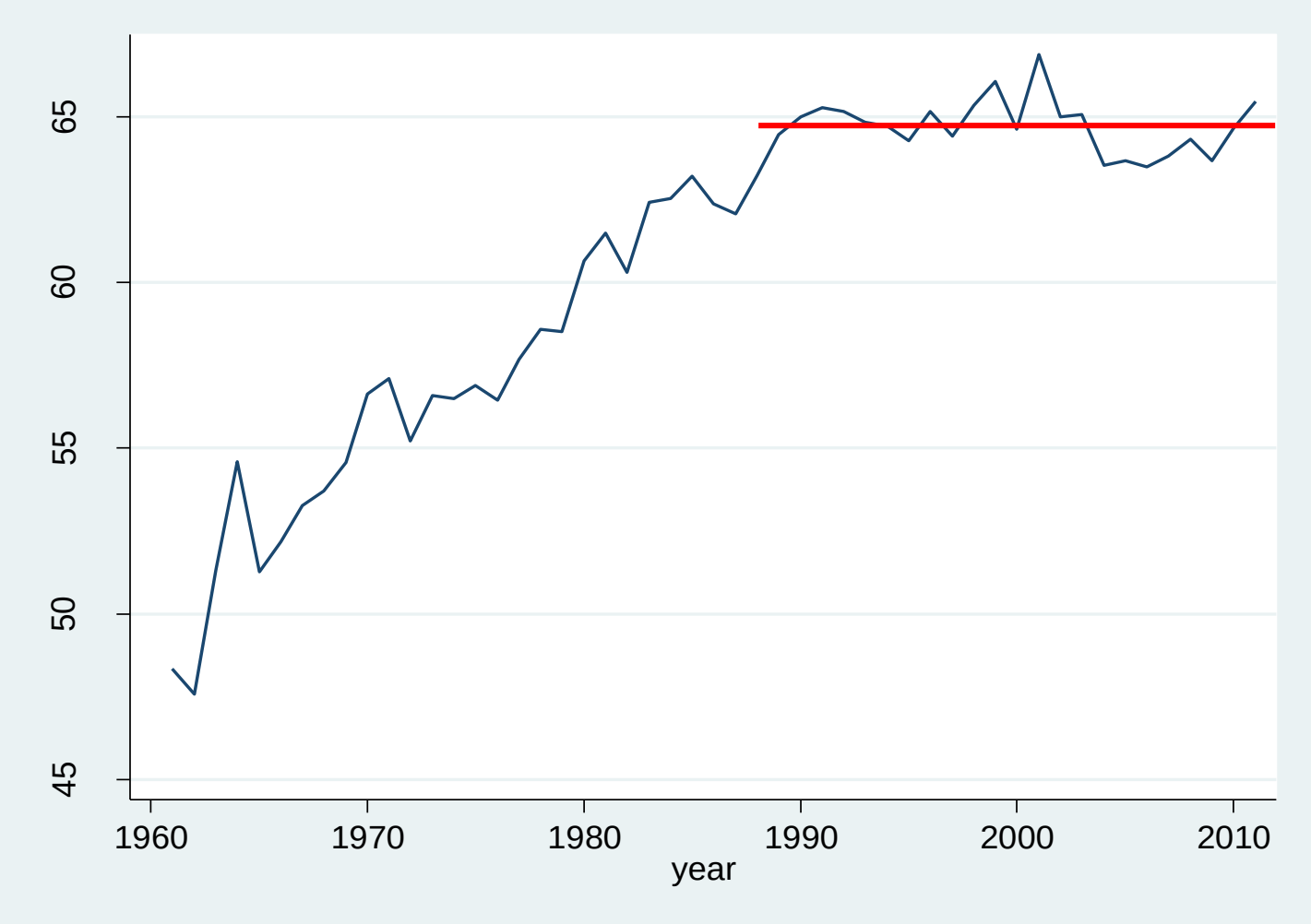
Yu Shangping with his nephew Li Ande and sister Yu Shangzhen
in Chala, Yunnan Prov. China

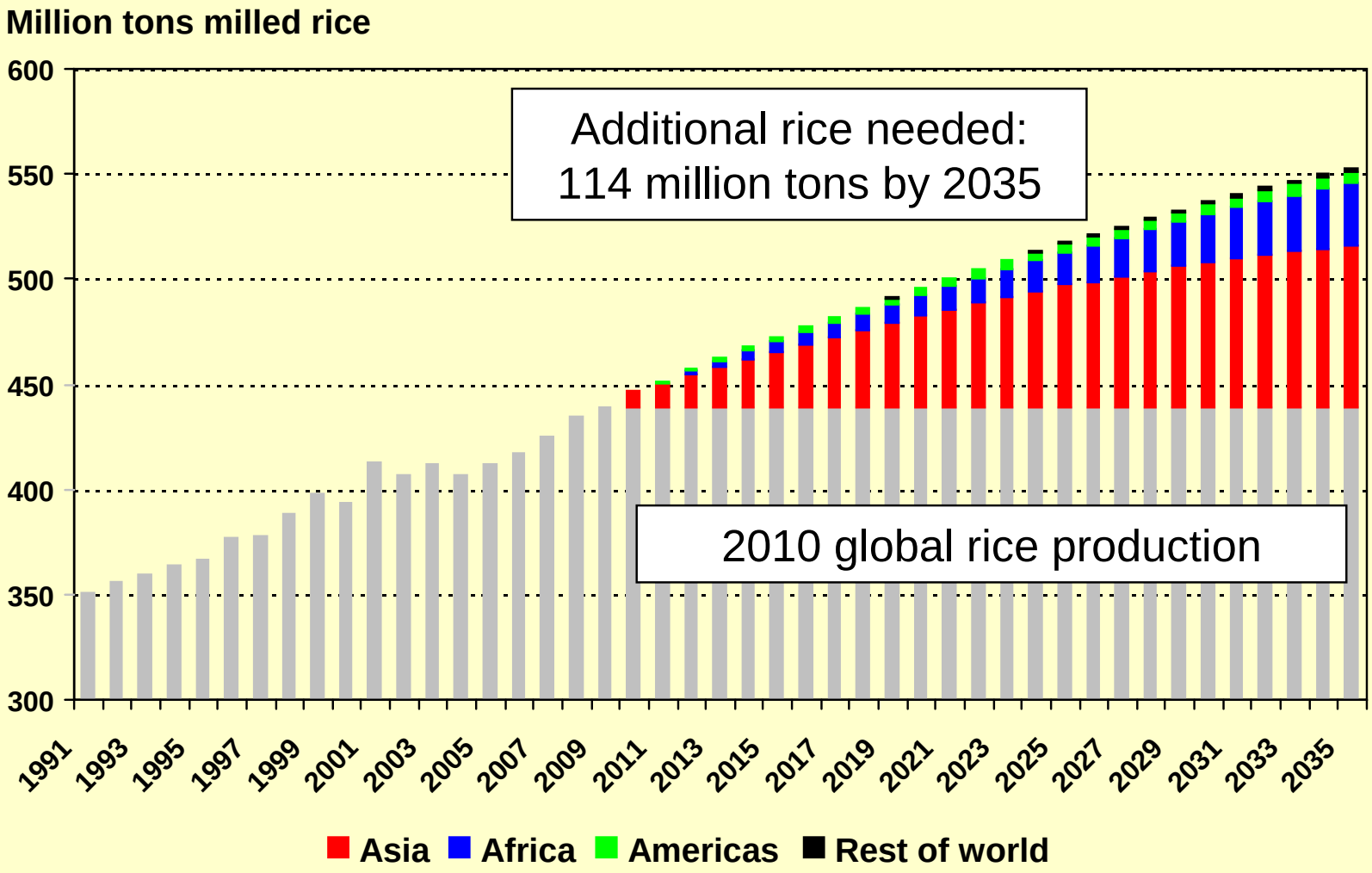
International Herald Tribune, May 6, 2013 , p.1

Rice Science for a Better World

Global per capita rice consumption has remained stable for last ~ 25 yrs



Global rice production increases needed to meet demand by 2035



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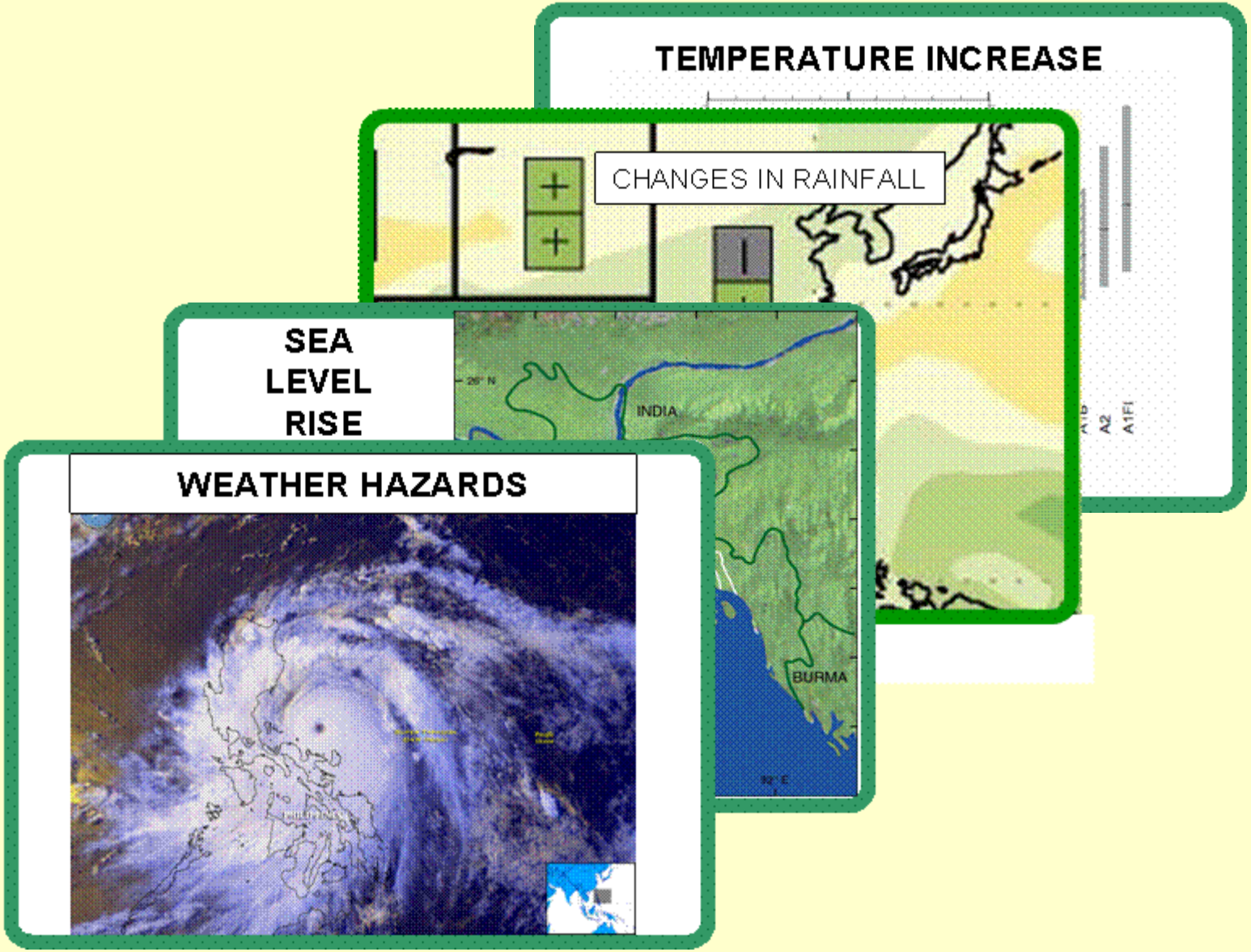
To Make Matters Worse: Climate Change Effects on Rice Production Hit Asia Hard



Rice Science for a Better World

Where Will the World's Rice Come From?

- **Ideally from increasing productivity on existing rice lands, mostly in Asia, (in 20+ years increasingly from Africa)**
- **BUT, in Asia:**
  - Land is moving out of rice
  - Labor is moving out of rice
  - Water is moving out of rice
- **Major changes in production practices and increases in efficiency *Just to stay where we are***
- **If Asia does not produce sufficient rice, the world will be food insecure**

IRRI
Rice Science for a Better World

IRRI

To Meet Tomorrow's Food Needs and Address Challenges of Nutrition and Poverty Under a Changing Climate

A Second Science–based Green Revolution is Needed

Rice Science for a Better World

Science–based?

- Tap the revolutions in genetics, molecular biology and plant physiology
- Link soils biology and chemistry to better understand and manipulate sustainable nutrient supply
- Exploit the explosion of computation capacity and remote sensing to model systems and link process at scales from the cellular through ecosystems and regions
- Proactively link the political and social dimensions of agriculture to technology development

IRRI

Cannot Overestimate Central Role of Genetic Resources for Coming Generations

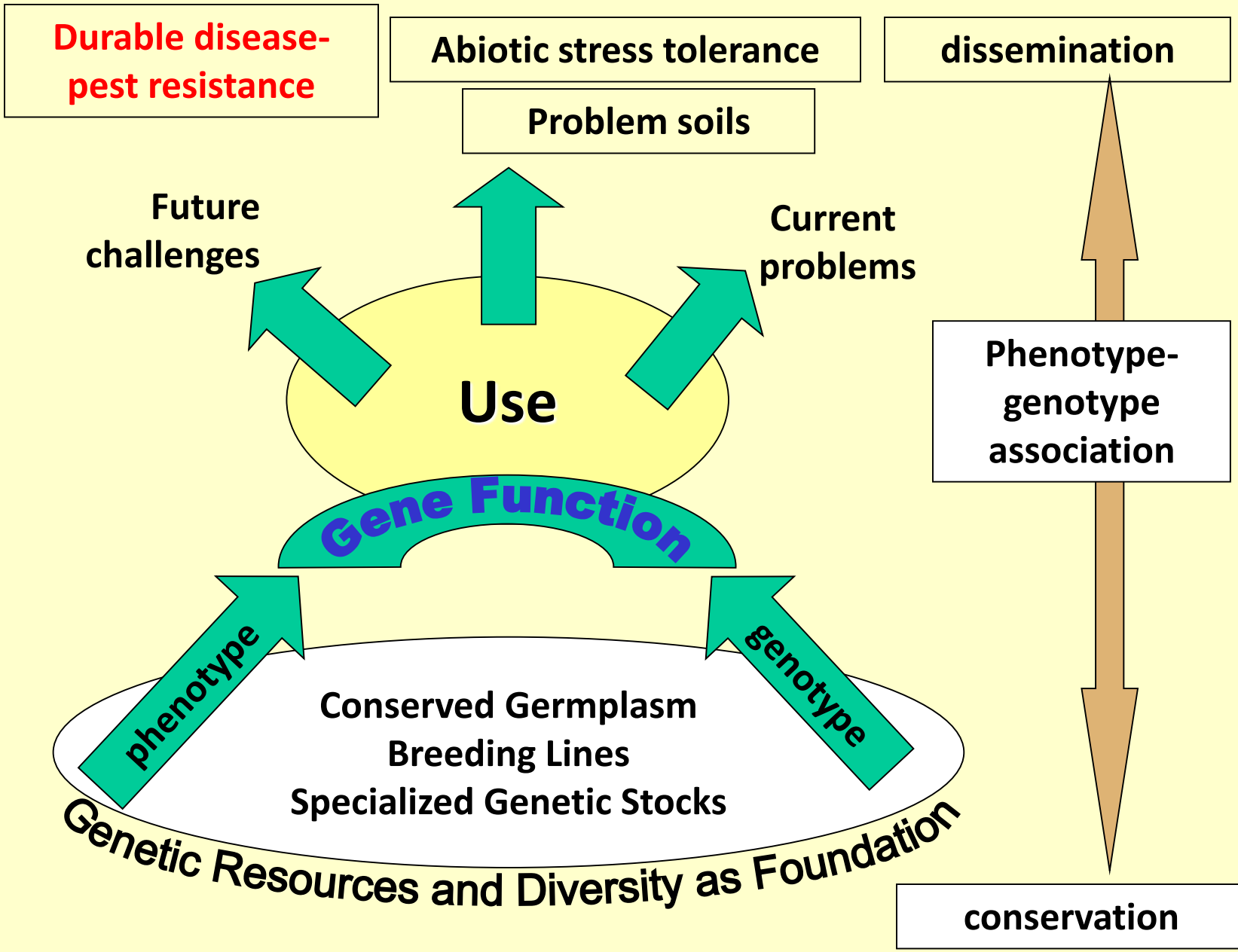
IRRI holds in trust the world's largest collection of rice varieties…> 110,000 accessions

Less than 5% has been used in breeding programs, but…

Completed full DNA sequencing of 3000 lines in 2014

Rice Science for a Better World

Developing a Genetic Resources Platform



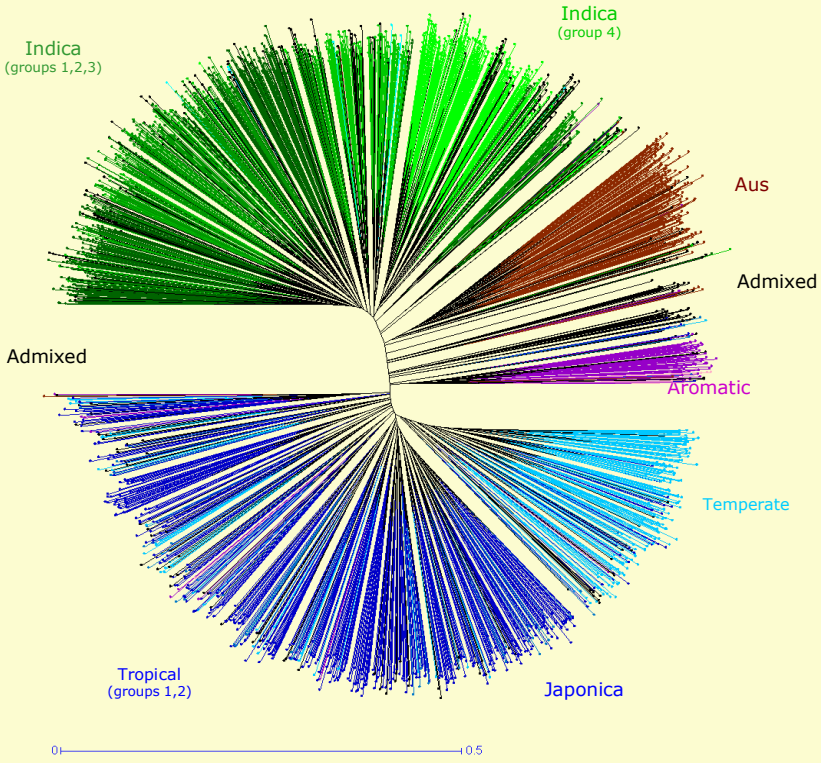
IRRI

Rice Science for a Better World

Sequence and Evaluate ~10,000 Rice Accessions

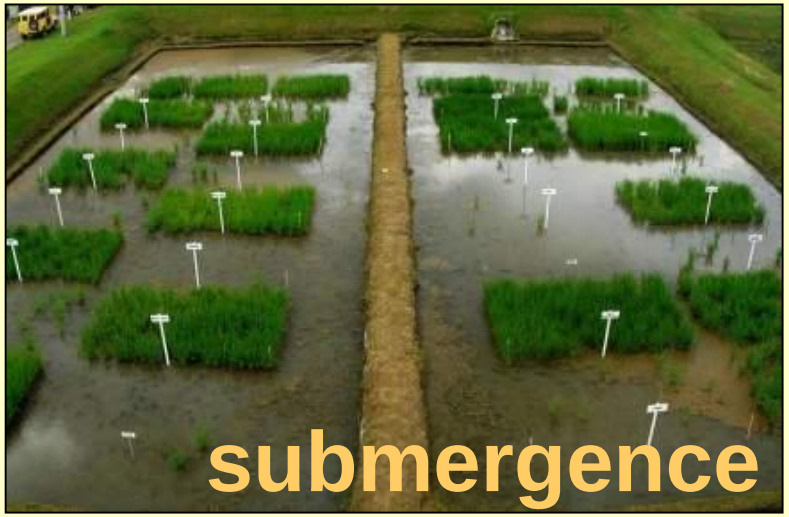
- Developing high-density genotyping Affy arrays with 1 M SNPs
- Includes newly discovered SNPs from >150 genomes and from other projects
- Initial genotype 3000 rice lines spanning range of diversity
- http://www.ricesnp.org
- Partners include Cornell, USDA, AfricaRice, CIRAD, Bayer CropSciences, Syngenta, CIAT,BGI – CAAS, USAID Linkage

3000 diverse rice lines clustered by molecular markers



- **Coordinated collaboration in bioinformatics & data management: adhere to highest standards of public access**

Making rice climate-ready



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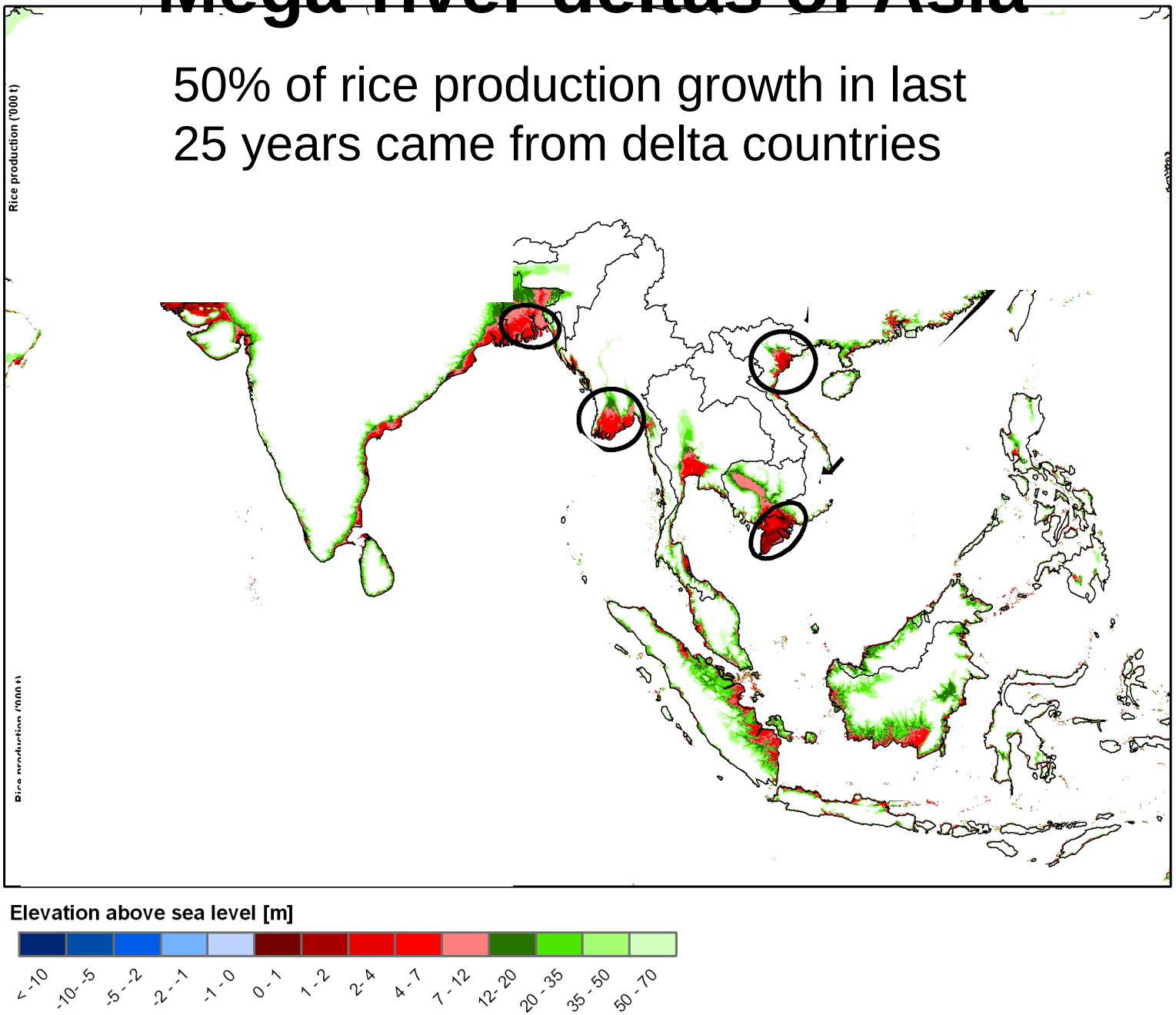
Mega-river deltas of Asia

50% of rice production growth in last 25 years came from delta countries



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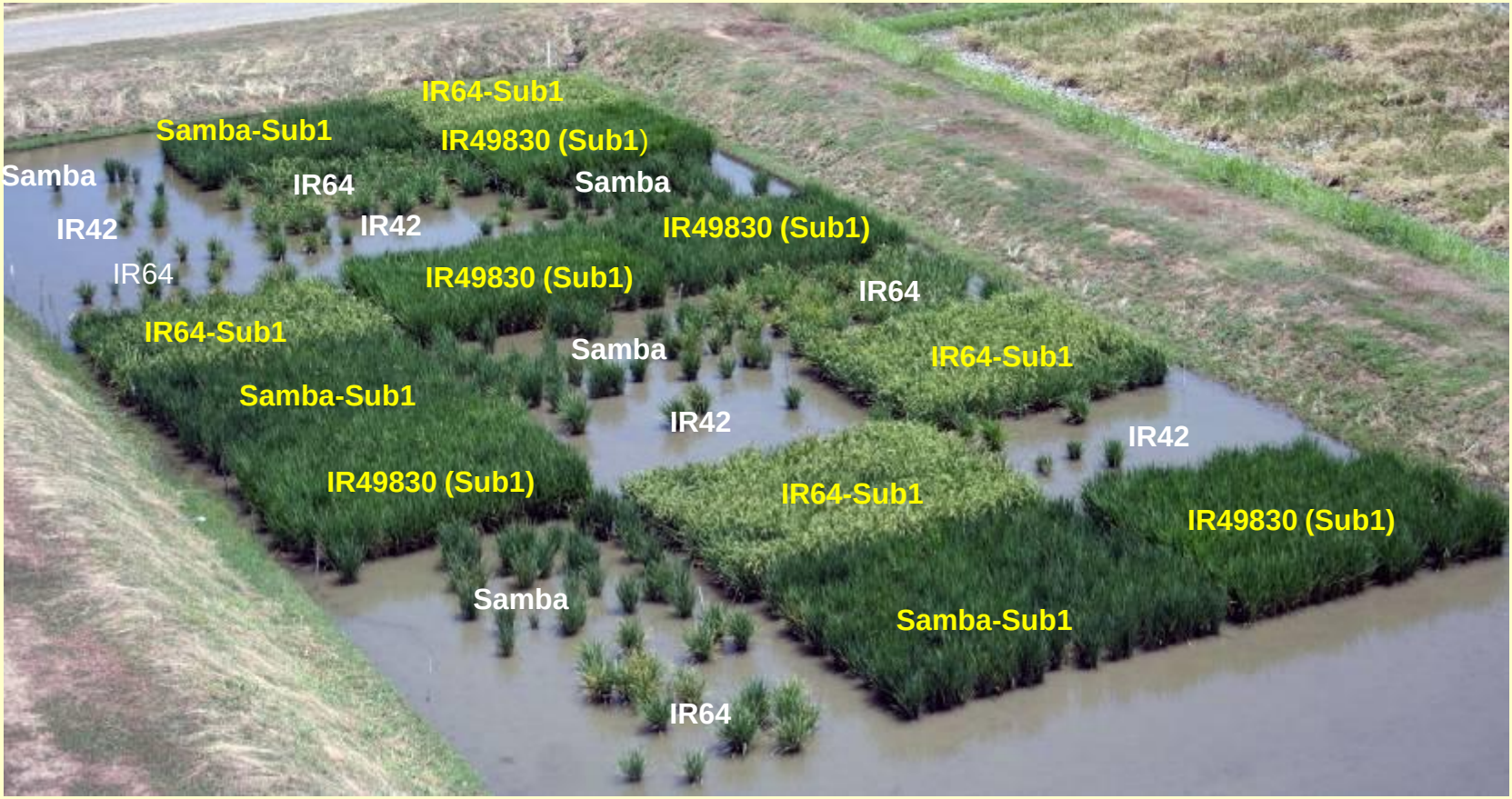
Breeding for submergence tolerance

- Large areas of rain-fed lowland rice have short-term submergence (eastern India to SE Asia); > 10 m ha
- Even favorable areas have short-term flooding problems in some years
- Flood tolerance identified in a traditional Indian variety FR 13A in 1978
  - Poor field performance and grain quality

New *Sub1* lines after 17 days submergence in the field at IRRI



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IRRI

Sub1 varieties: help poor farmers cope with frequent flooding

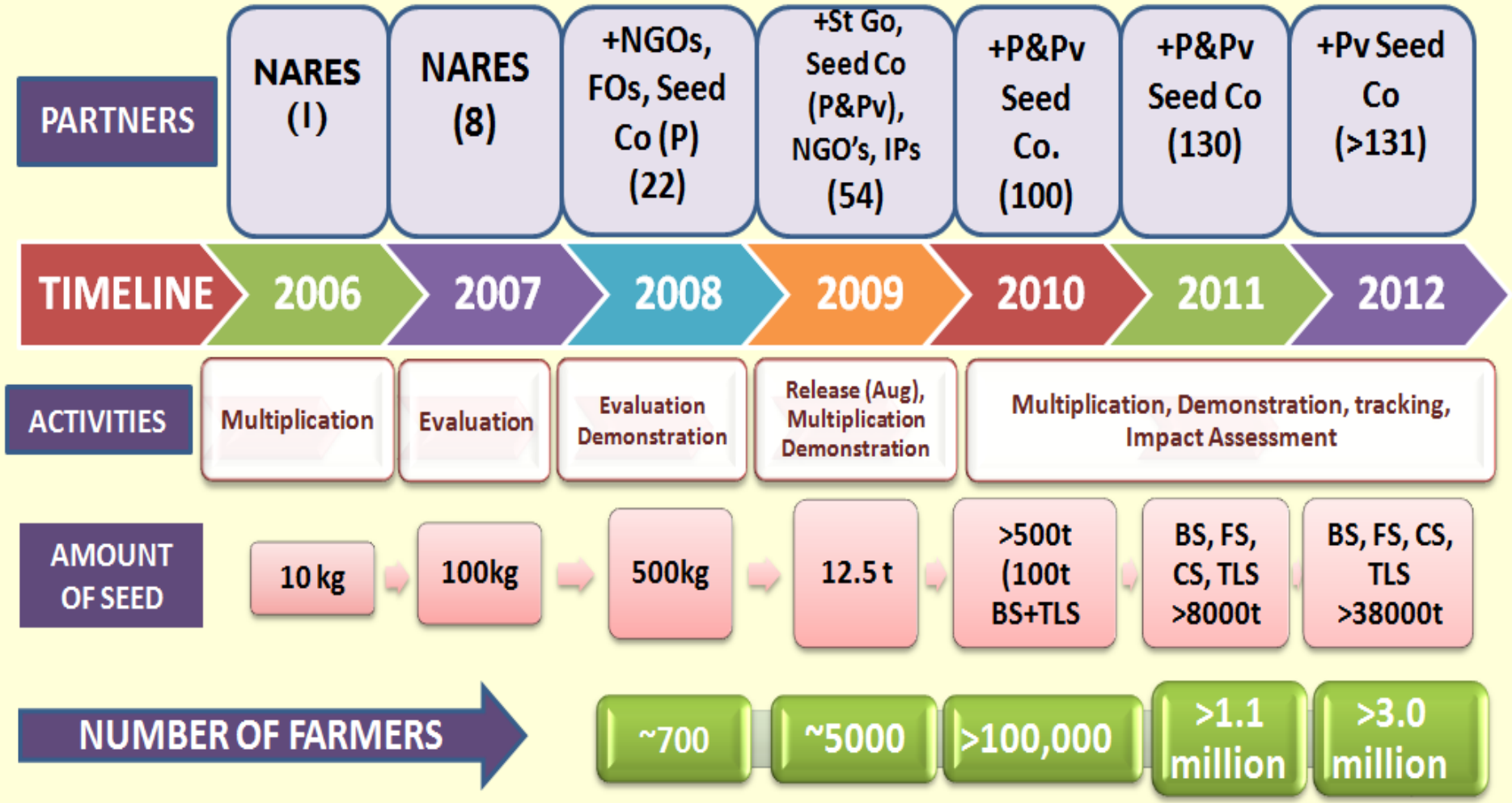
Mr. Asha Ram Pal
Village Palia Goa,
District Faizabad,
Uttar Pradesh

Major support from Japan USAID, B&MGF, GOI enables us to reach >5M farmers by 2015…millions more over the next few years

Released in Bangladesh, India and Philippines 2009… Nepal in February 2011

Rice Science for a Better World

Stress tolerant rice – accelerate adoption by farmers through private sector engagement



2013: Sub1 Varieties reached ~ 4 m farmers on ~1.7 m ha

Jharkhand, Eastern India, September 2013

This study "… indicates that scheduled castes are likely to be a major beneficiary from the spread of Swarna- Sub1 in India."

SCIENTIFIC REPORTS

OPEN

SUBJECT AREAS:
FIELD TRIALS
AGRICULTURAL GENETICS

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Flood-tolerant rice reduces yield variability and raises expected yield, differentially benefitting socially disadvantaged groups

Manzoor H. Dar[1], Alain de Janvry[2], Kyle Emerick[2], David Raitzer[3] & Elisabeth Sadoulet[2]

[1]International Rice Research Institute, New Delhi, India, [2]University of California at Berkeley, Berkeley CA, USA, [3]International Rice Research Institute, Manila, Philippines.

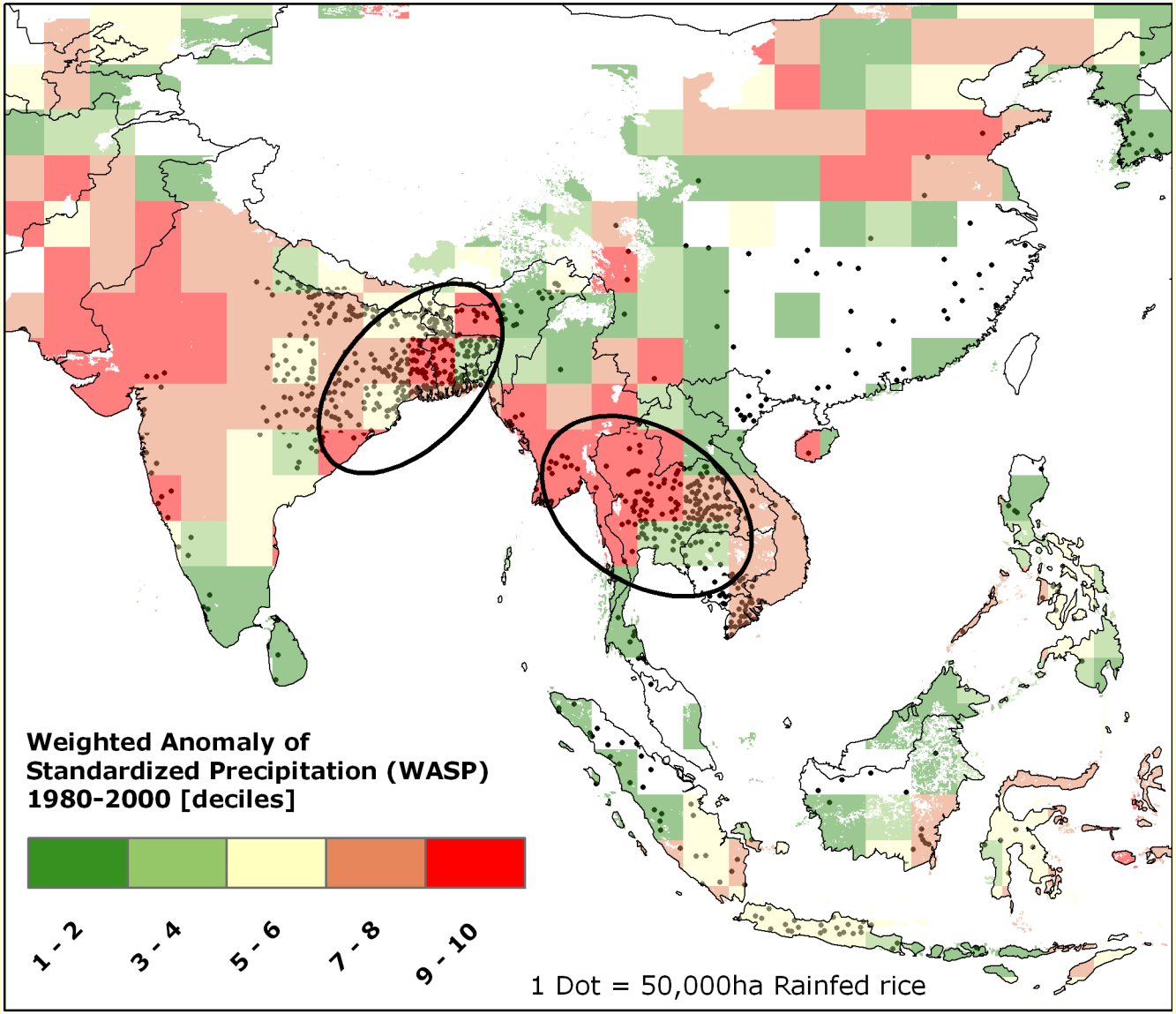
Approximately 30% of the cultivated rice area in India is prone to crop damage from prolonged flooding. We use a randomized field experiment in 128 villages of Orissa India to show that Swarna-Sub1, a recently released submergence-tolerant rice variety, has significant positive impacts on rice yield when fields are submerged for 7 to 14 days with no yield penalty without flooding. We estimate that Swarna-Sub1 offers an approximate 45% increase in yields over the current popular variety when fields are submerged for 10 days. We show additionally that low-lying areas prone to flooding tend to be more heavily occupied by people belonging to lower caste social groups. Thus, a policy relevant implication of our findings is that flood-tolerant rice can deliver both efficiency gains, through reduced yield variability and higher expected yield, and equity gains in disproportionately benefiting the most marginal group of farmers.

The world currently faces a major food security challenge to which crop genetic improvements can make a significant contribution. According to the FAO, world food production will need to increase by 70% by the year 2050 in order to meet growing demand[1]. Since rice is one of the world's three main staple foods, productivity gains in rice are essential to achieve this goal, especially for Asia where there is no room for land expansion. Major gains in productivity were achieved in the 1970's with Green Revolution technologies targeted at the better-endowed areas under irrigation[2]. Two issues have subsequently challenged scientists. The first is that maximum yields achieved in the better-endowed areas have stagnated at around 11 tons per ha, with little prospects for significant improvements[3]. Technological innovations for these areas have basically been directed at maintenance research and at compensating for losses in soil fertility and declines in water availability. The second issue is that the Green Revolution has remained elusive for rainfed areas, particularly those affected by flash flooding and drought[4–6]. Major efforts have been undertaken by rice scientists around the world to bring productivity gains to rainfed areas prone to these environmental stresses.

We focus here on the development of flood-tolerant rice through genetic improvements. Precision in the transfer of genes conferring flood tolerance has been greatly facilitated by marker-assisted selection (MAS), allowing for minimization of undesirable properties such as low yield under non-stress conditions[7,8]. Two alternative paths have been followed. One consists of introducing into modern rice varieties quantitative trait loci that contain the SNORKEL1 and SNORKEL2 genes, which induce elongation in traditional deepwater rice varieties, allowing them to survive during periods of prolonged flooding[9]. The second path involves the SUB1 quantitative trait locus that responds to ethylene buildup by restricting elongation, the natural response of the rice plant[10,11]. A particular advancement is the introduction of the SUB1 locus into Swarna (IRTP12715), India's most popular rice variety[7,10]. The resulting Swarna-Sub1 (IR05F102) maintains all the properties of Swarna while acquiring submergence tolerance. An MAS approach was used to introgress the SUB1 locus into Swarna[10].

Swarna-Sub1 has been shown to withstand floods of up to 17 days in agricultural trials[12,13]. The potential impact of the technology in India alone is large. Of the country's 44 million hectares cultivated in rice, rainfed lowlands where flash flooding is common and Sub1 varieties would be beneficial account for approximately 12–14 million hectares, or 30 percent of the cultivated rice area. There would remain an additional 3–4 million hectares where water may remain stagnant for extended periods of time where even Sub1 varieties will not fare well. Swarna is

Variation in Rainfall = Risk of Drought

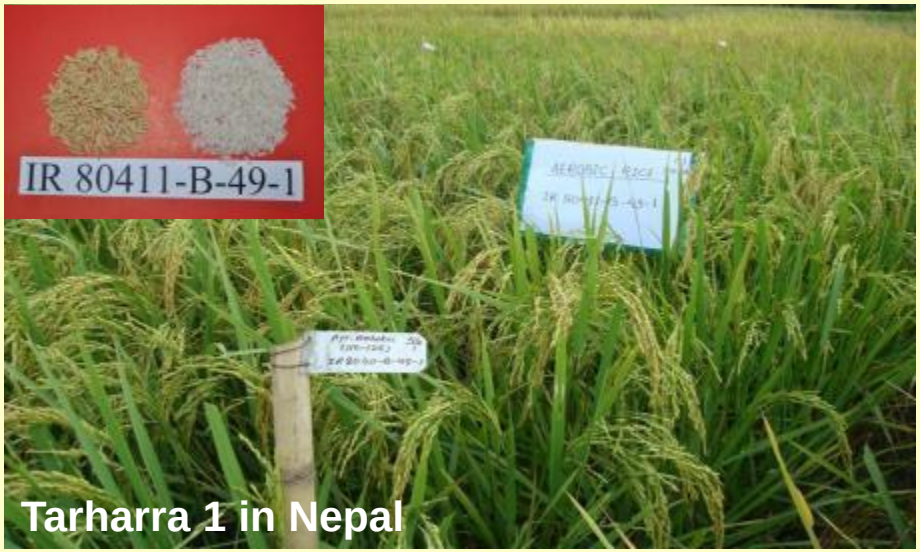


Rice Science for a Better World

Drought tolerant varieties

- Drought tolerant varieties across S Asia 2009-14
- Yield advantage of 0.8-1.2 t/ha under moderate to severe drought, but with no penalty under non-stress conditions

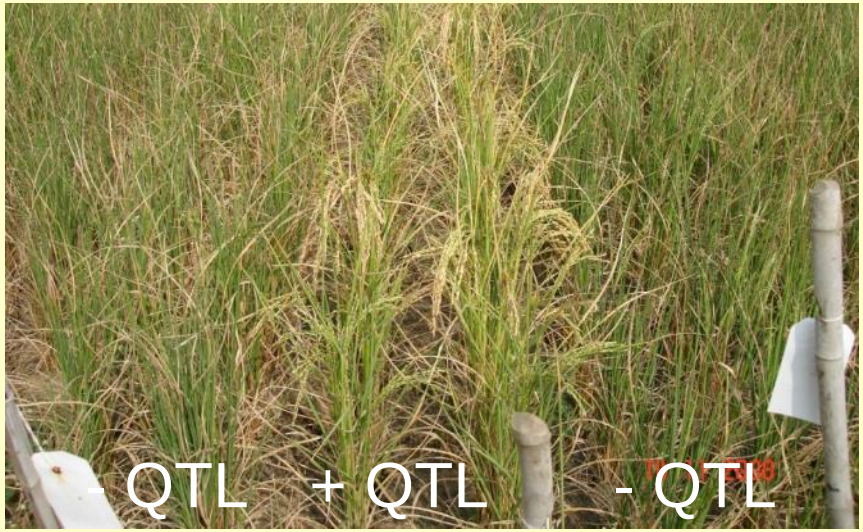
Sahbhagi dhan in India



Tarharra 1 in Nepal

Sahod Ulan 1 in Philippines

2 in 1: Drought + submergence tolerance



- **Three drought yield QTLs pyramided in Swarna sub1**
- **BC_4F_2 population with three QTLs under genotyping at IRRI**
- **Anjali, Savitri, TDK 1, Saro 5, Supa, NSICRc 222, MR219, MRQ74 improvement underway**

Swarna

Swarna + DTY

Rice is growing near its max temperature tolerance (33C)

- Extremely difficult to change basic biology of temperature sensitivity
  - Rice flowering is the only stage at which temperature is critical
  - Rice normally flowers at mid day…
- Maybe the best strategy is to just run away?

Conserving traditional heirloom rice varieties for indigenous livelihoods

Wild Species of *Oryza*: The Resource to Meet Tomorrow's Challenges

O. alta	O. minuta	O. brachyanta	O. rufipogon	O. longistaminata

- ***Drought, salt, flood, heat…***
- ***Insect resistance***
- ***Disease resistance***
- ***Yield and nutrient use***

Rice Science for a Better World

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Transfer of natural salt tolerance from *Oryza coarctata* (KKLL genome), a wild species that grows well in brackish water

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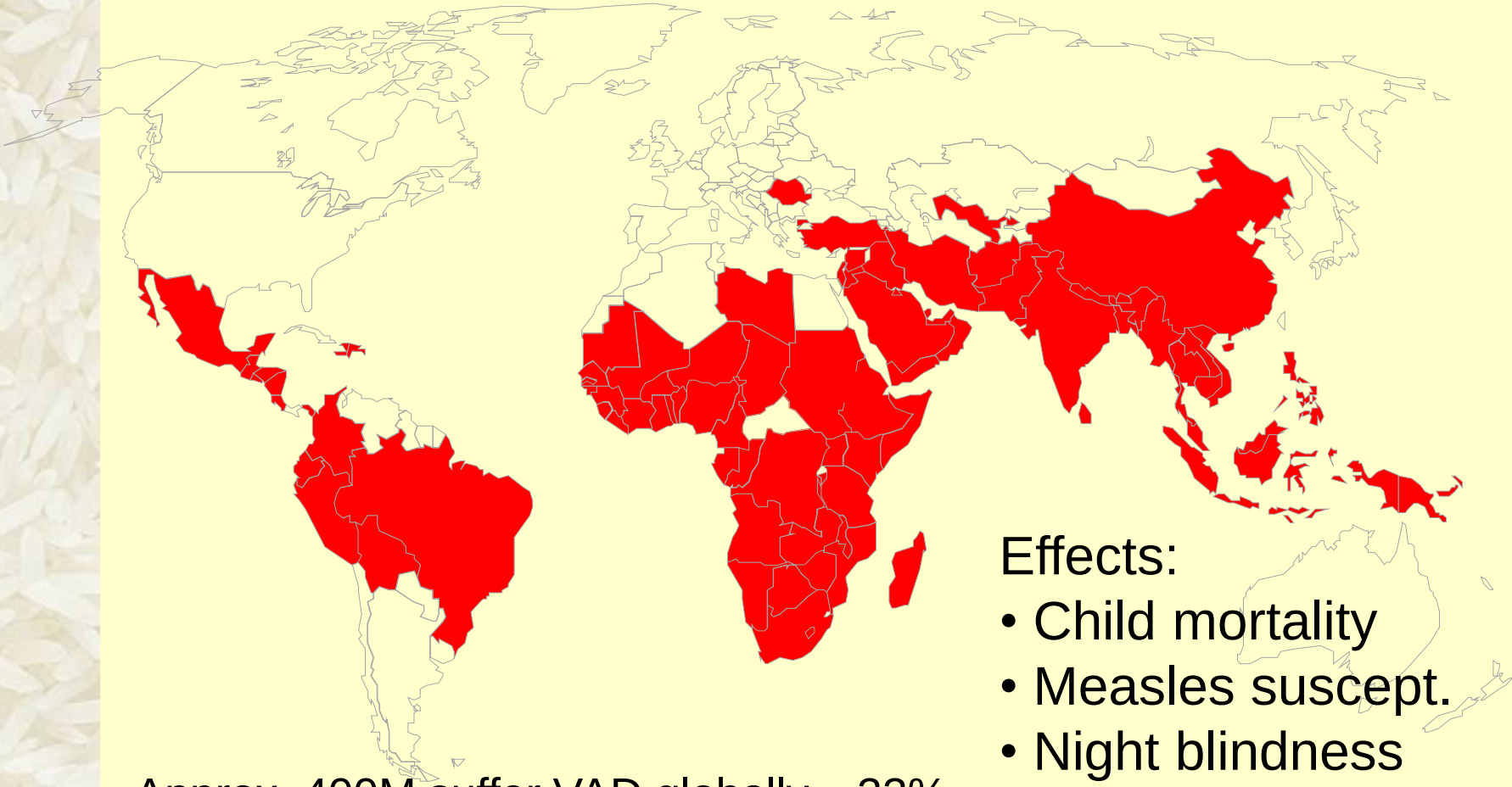
Even in wild relatives,

some traits are not found in rice

Rice Science for a Better World

Clinical and Sub-clinical Vitamin A Deficiency



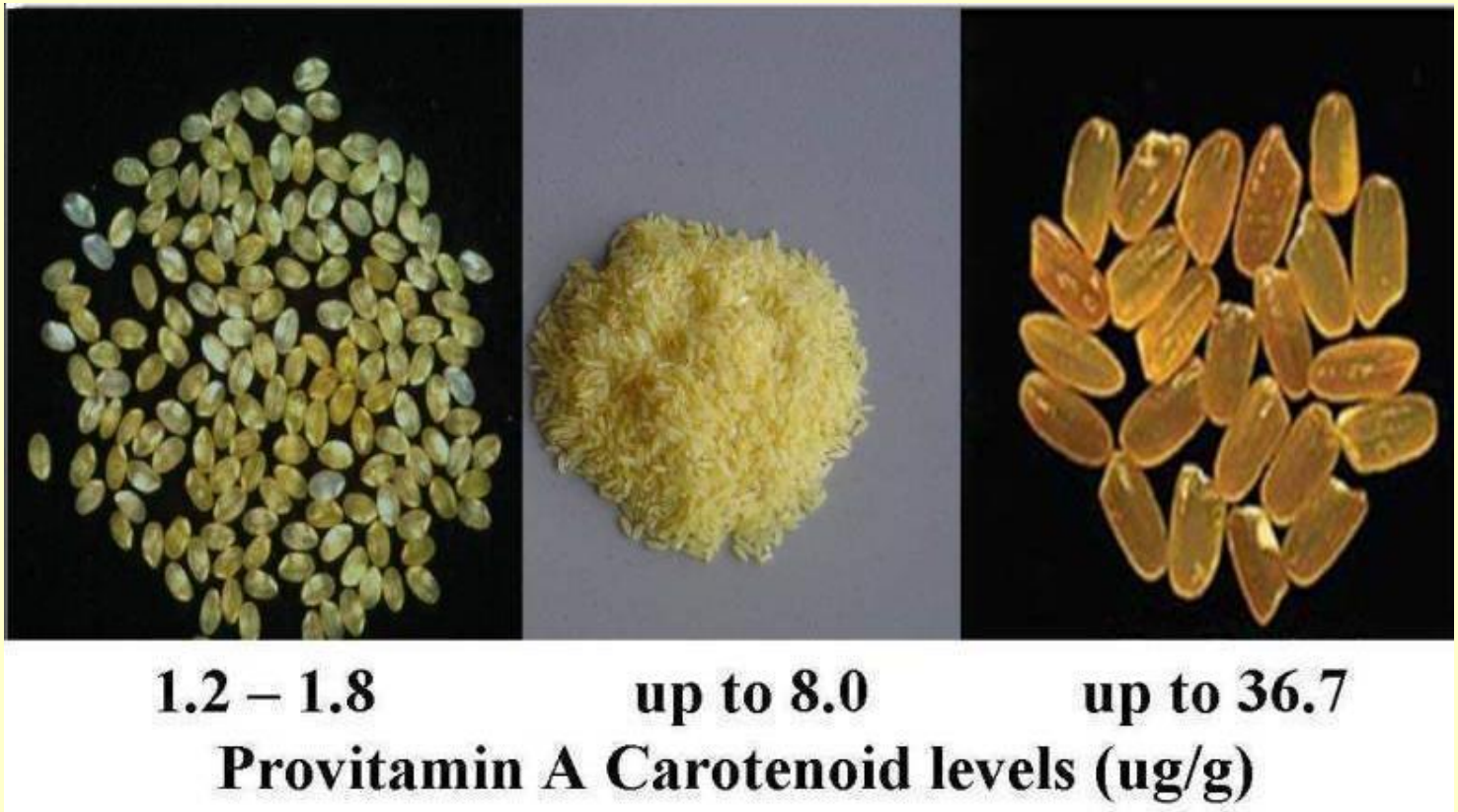
Approx. 400M suffer VAD globally, ~33%
SE Asia 100 -140 million children suffer from VAD

Effects:

- Child mortality
- Measles suscept.
- Night blindness
- Corneal scarring
- Blindness

Micronutrient Initiative 2004

Combating vitamin A deficiency among the poor: Golden Rice



Work on Golden Rice began in late 1980s…
to consumers in 201?

Can Golden Rice Provide Sufficient Vitamin A?

β-Carotene in Golden Rice is as good as β-carotene in oil at providing vitamin A to children

Guangwen Tang, et al. 2012
Am J Clin Nutr 2012;96:1–7.

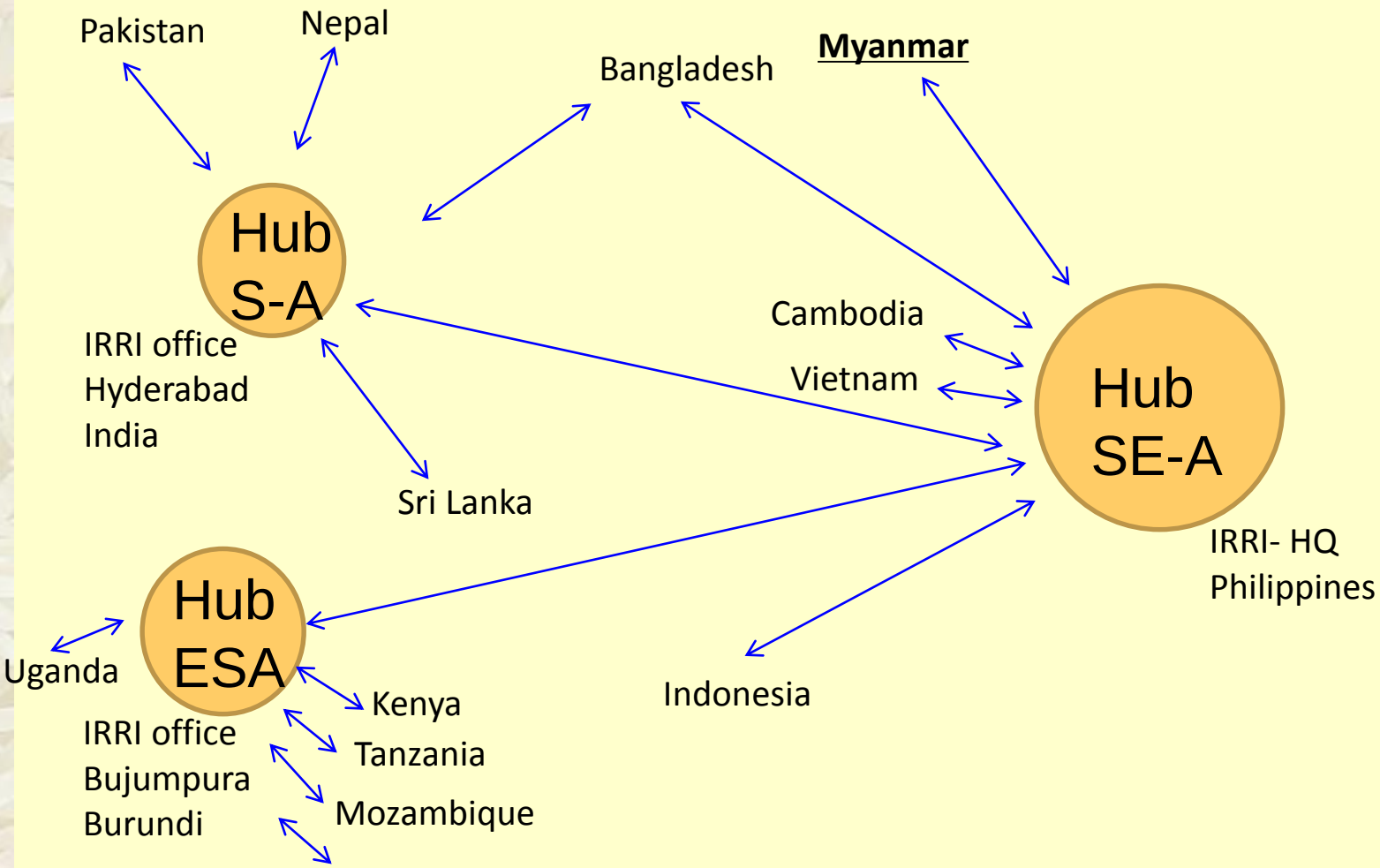
GreenPeace ridiculed prototype Golden Riceas having insufficient *B* – carotene

1 Bowl of Golden Rice (50g uncooked, 150 g cooked) Provides 60% of Recommended Daily Dose for Chinese Children 6 years of age and younger

IRRI

Rice Science for a Better World

IRRI – GRiSP breeding hubs for South East and South Asia and ES-Africa



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What do we do about managing our rice crop more efficiently?

Examples of nutrient and water management

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Rice and Water

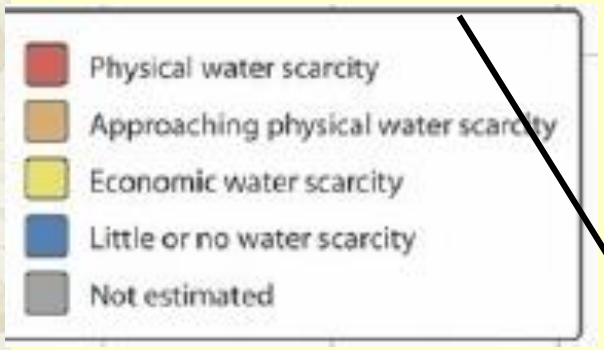
40% of fresh water used in Asia goes to rice production

Puddling soil and transplanting seedlings controls weeds, improves nutrient supply & holds water later in season

As labor and water use change, what does this mean for rice production?

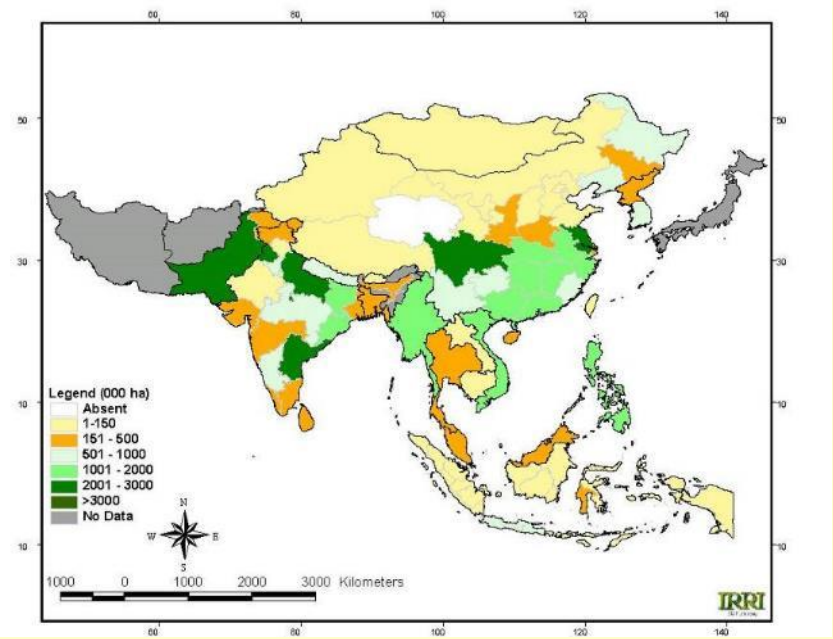
Expected increasing water scarcity

Comprehensive Assessment Water Management in Agriculture 2007



2025: 15-20 million ha irrigated rice will suffer some water scarcity

Asia WS irrigated rice



IRRI Data base (GIS laboratory)

Rice Science for a Better World

Water saving options for rice

	Conventional	Safe AWD	Dry seeded	Aerobic rice
Land prep	Puddled	Puddled	Not puddled	Not puddled
Establishment	Transplant; wet seed	Transplant; wet seed	Dry seed	Dry seed
Water	Flooded; saturated	Saturated; mild drying	Early: drained; then saturated	Drained
Soil aeration	Anaerobic	Anaerobic; mild drying	Aerobic; then anaerobic	Aerobic

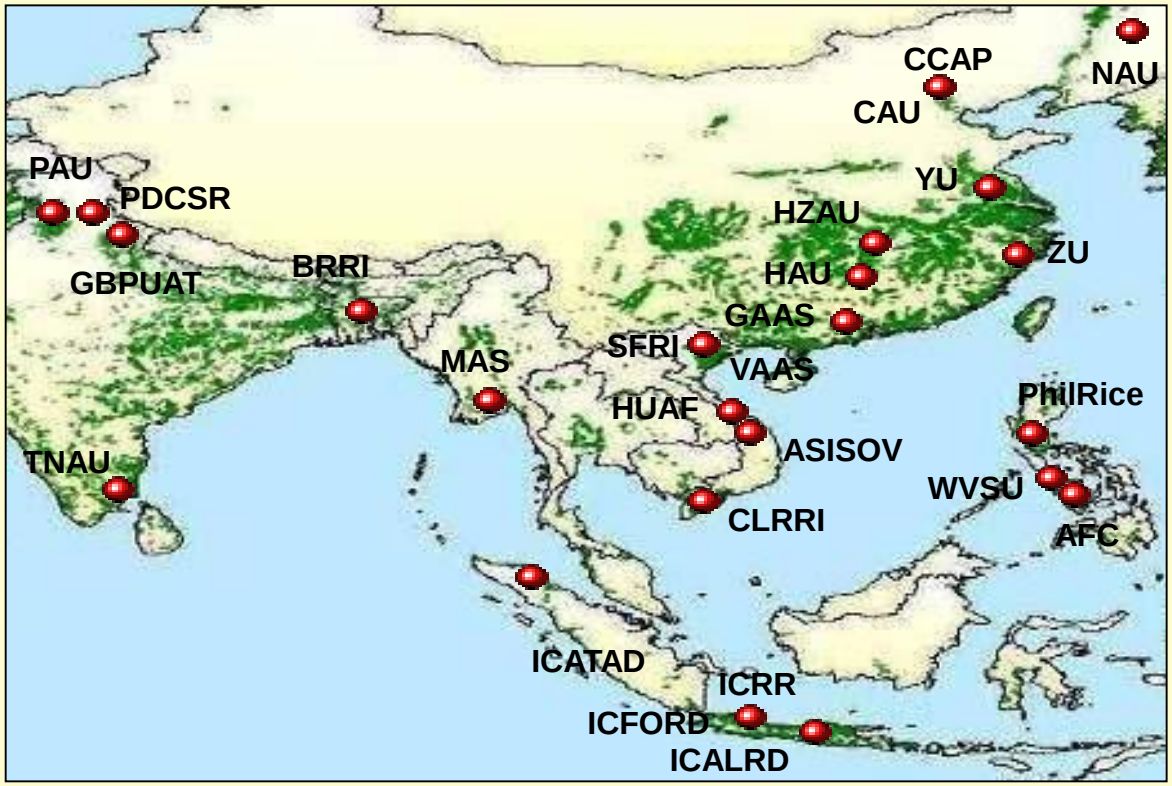
Conventional

Safe AWD

Dry seeded

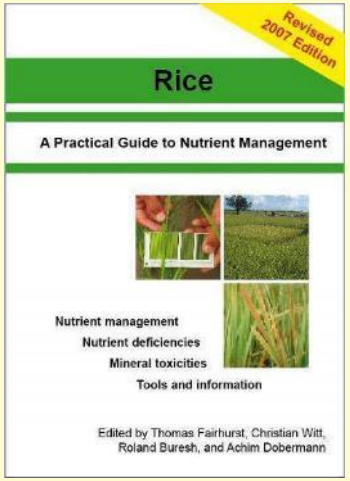
Aerobic rice

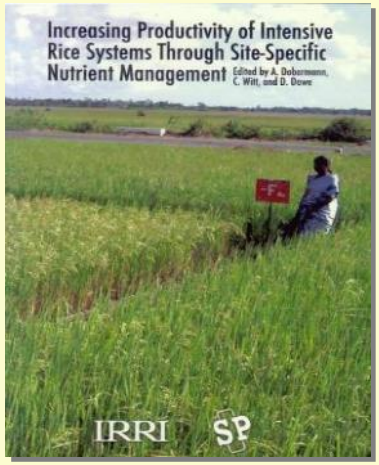
15 years of research provides the science for ‘precise’ field-specific nutrient management



Partnerships of > 15 years (1996-present)

Science is well documented





Tools are available for farmers

Farmers need quick and easy access to customized, science-based recommendations

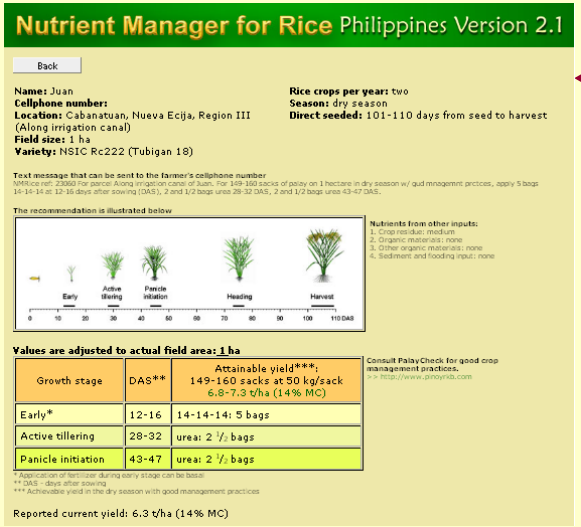
Web

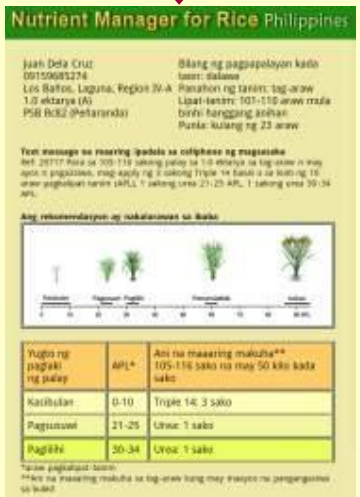
Smartphone

GSM mobile

Farmer calls 2378 using Globe SIM

Interactive Voice Response implementation box





SMS output

Web output

Smartphone output

Converted to HTML 5

Connect farmers with relevant agricultural science and services:

Suite of compelling services and financial products

Insurance

Input providers

Microfinance

Service providers

Marketing

Interactive Apps --- providing management guidelines

1. Invest wisely at start of season
   - Nutrient Manager and Rice Crop Manager
2. Protect investment during season
   - Rice Crop Doctor

Product development and testing

Research

Consolidation of knowledge

Validation

Testing with farmers

IRRI

Particular attention to women stakeholders

Burundi: ex-combatant women trained in novel rice farming technologies

"In my family… we were eating only once a day… now we eat twice a day"

Rice Science for a Better World

For sound medium and long term planning, what do we need to know?

Location specific, timely and accurate information on rice production, supplies, and trends

In particular:

- What is the harvested area?
- When will it be harvested?
- What is the yield?

A combination of remote sensing and crop yield modeling can provide this information under certain conditions

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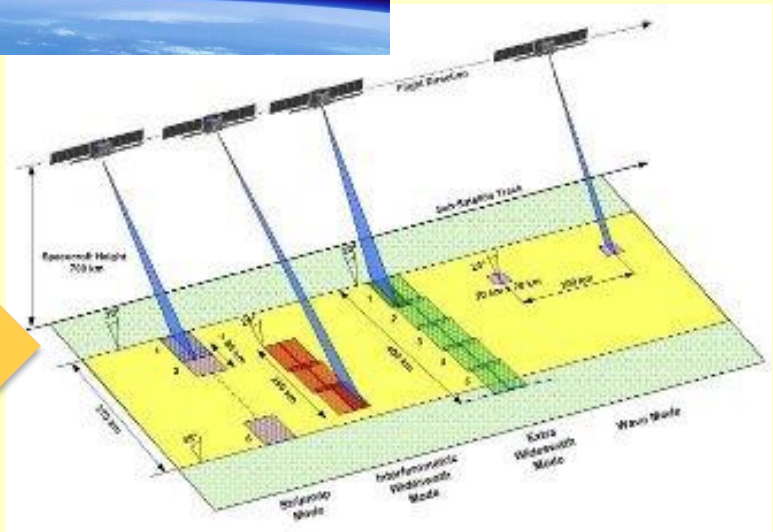
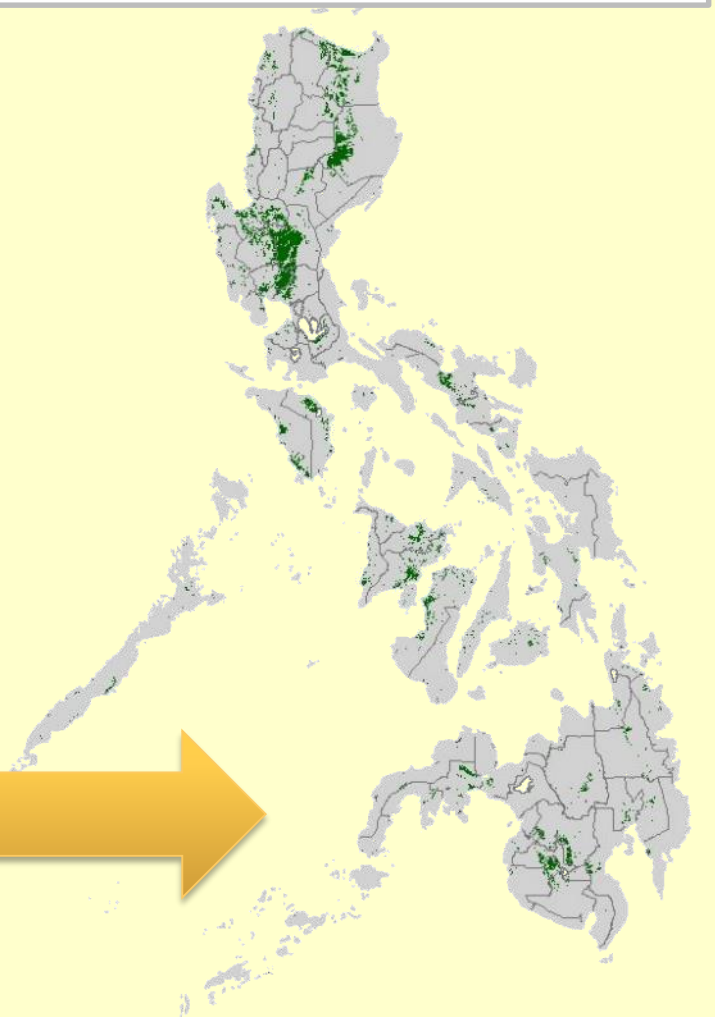
Mapping rice from space

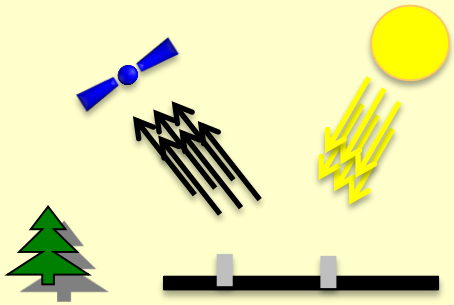
Regular monitoring of rice growing areas using satellite imagery, modeling and regional ground-truthing to accurately estimate rice area, rice production and damage from calamities.



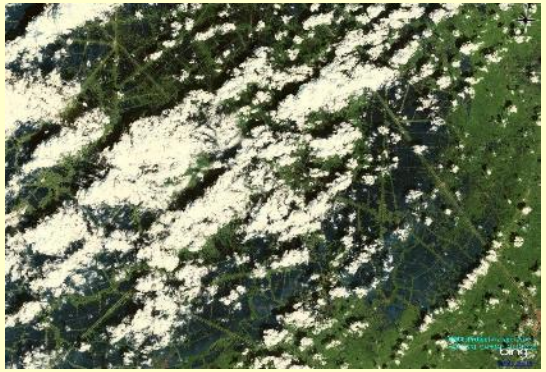


How the technology works

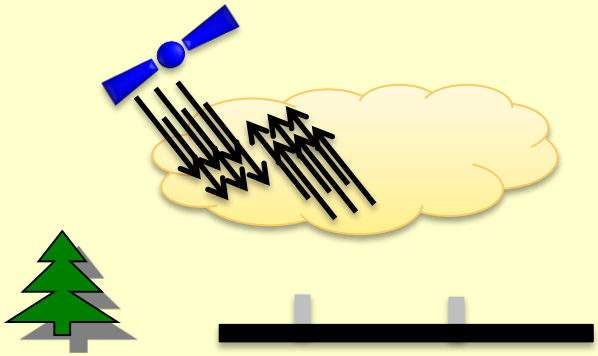
Optical data is based on sunlight



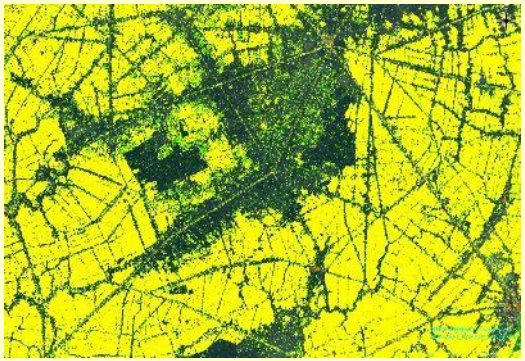
and clouds are a problem



Radar data is not based on sunlight



can see through the clouds



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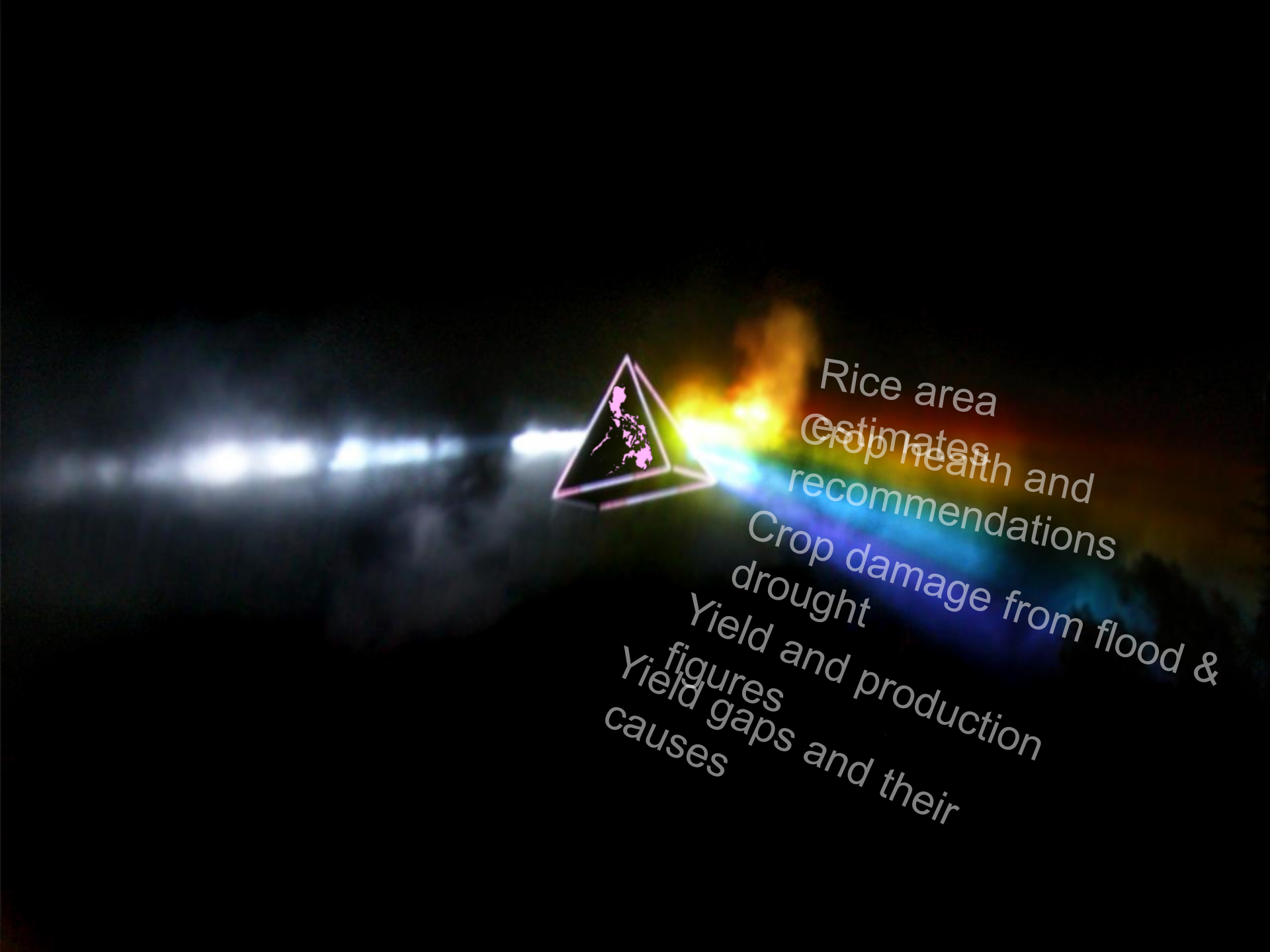
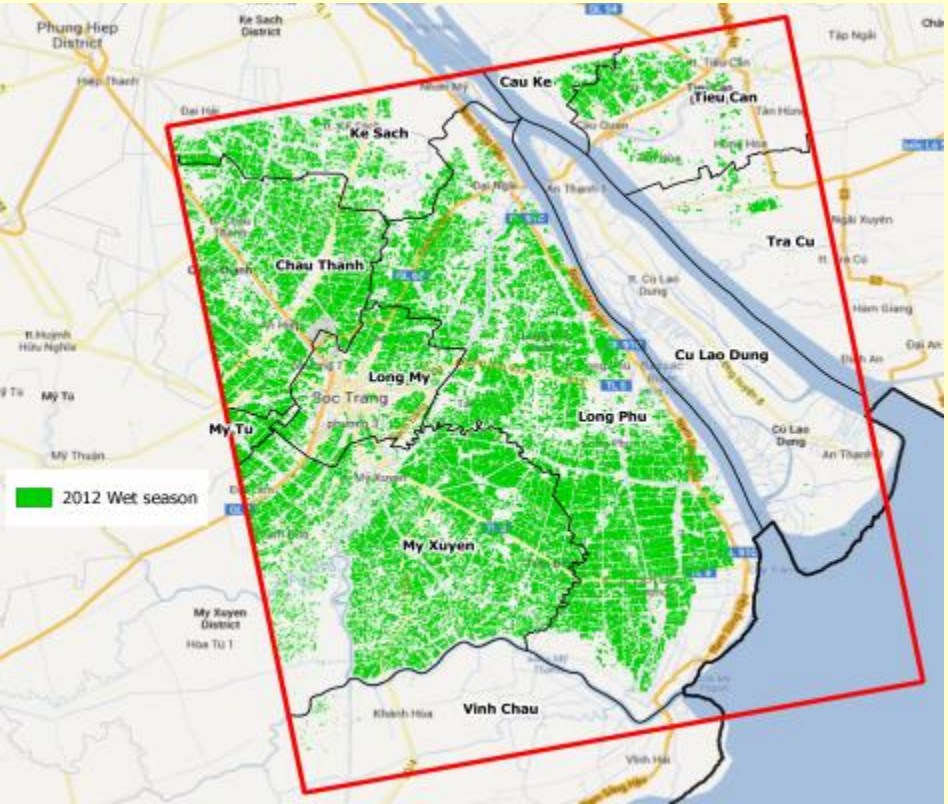
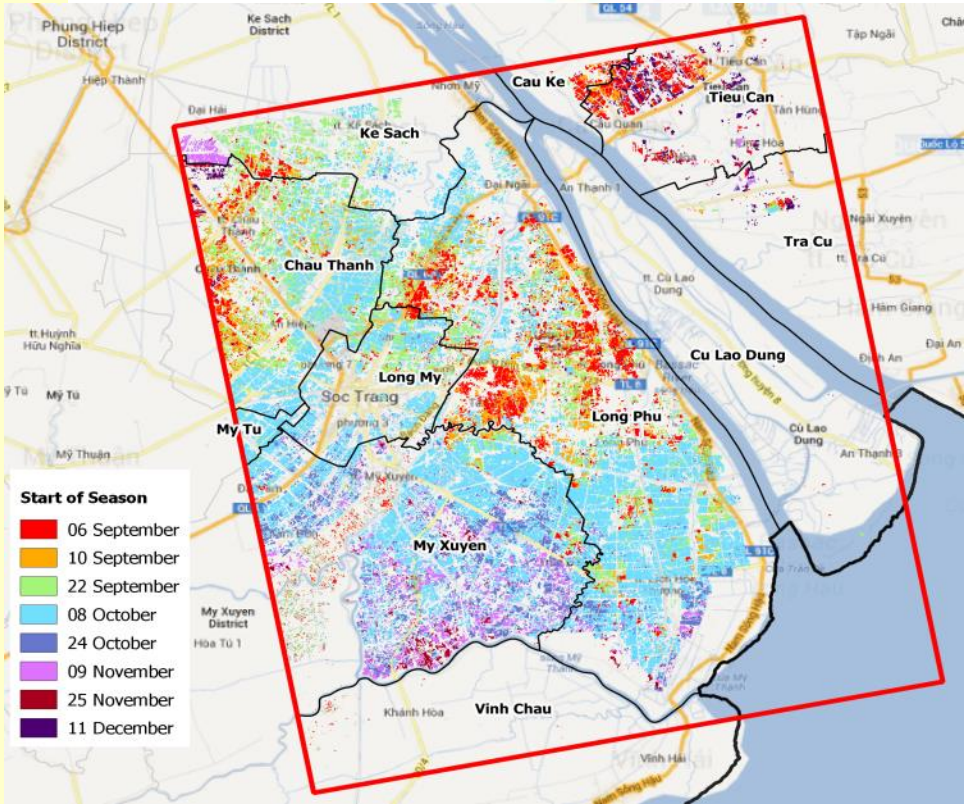
Rice Science for a Better World


Rice area estimates
Crop health and recommendations
Crop damage from flood & drought
Yield and production figures
Yield gaps and their causes

Mekong Delta, Vietnam

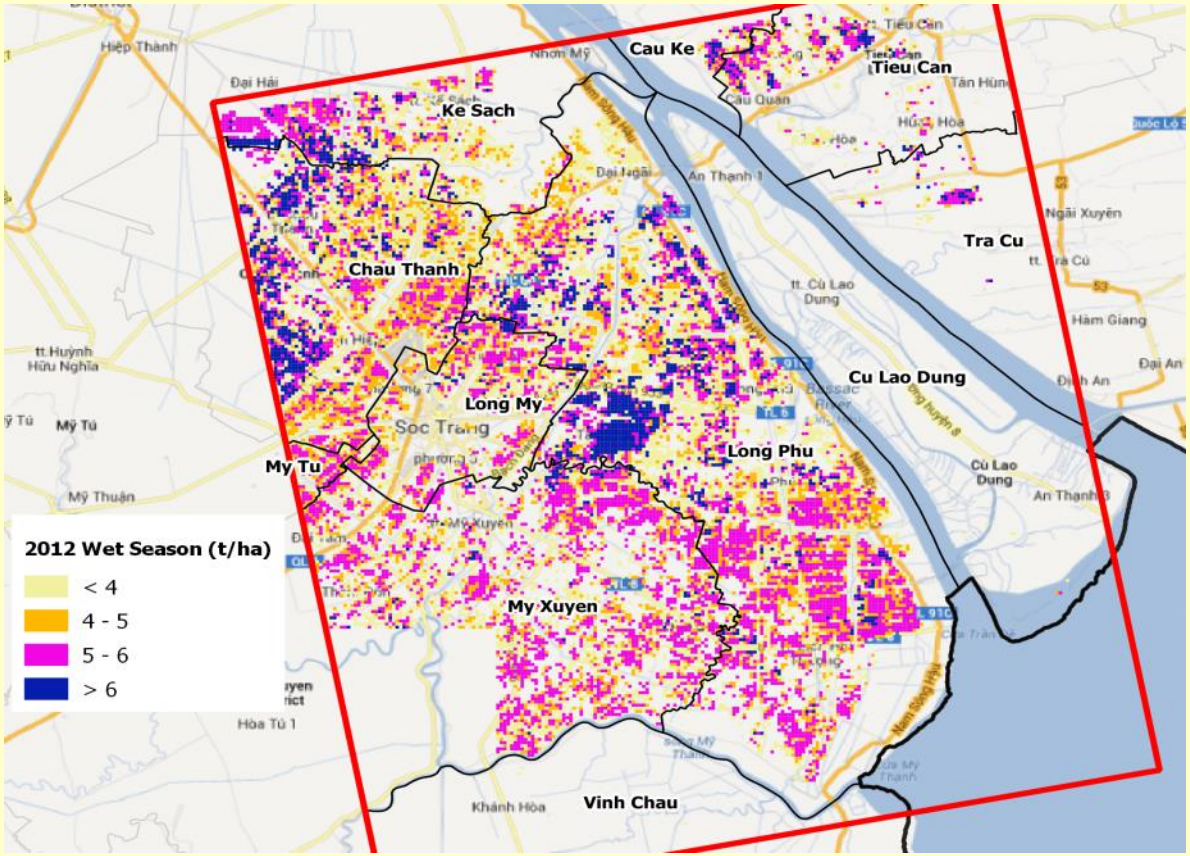
- **Over 85% accuracy in the rice area estimates at 3m resolution.**
- **SAR can also capture the variability in planting dates and cropping patterns.**



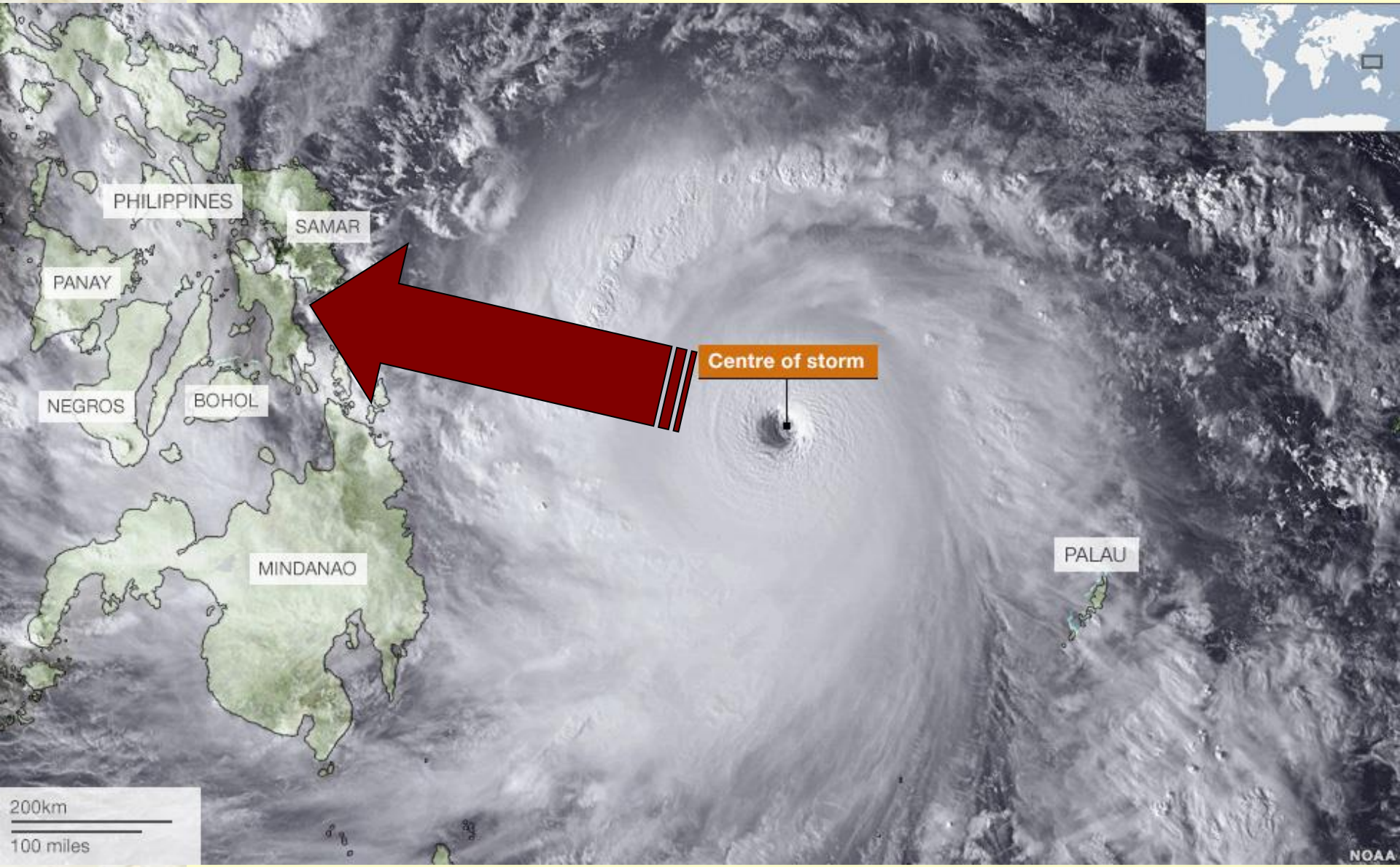


Mekong Delta, Vietnam

Yield and production estimates at the end of season, plans to generate yield forecastsat 30 and 60 days before harvest.



Typhoon Haiyan November 2013



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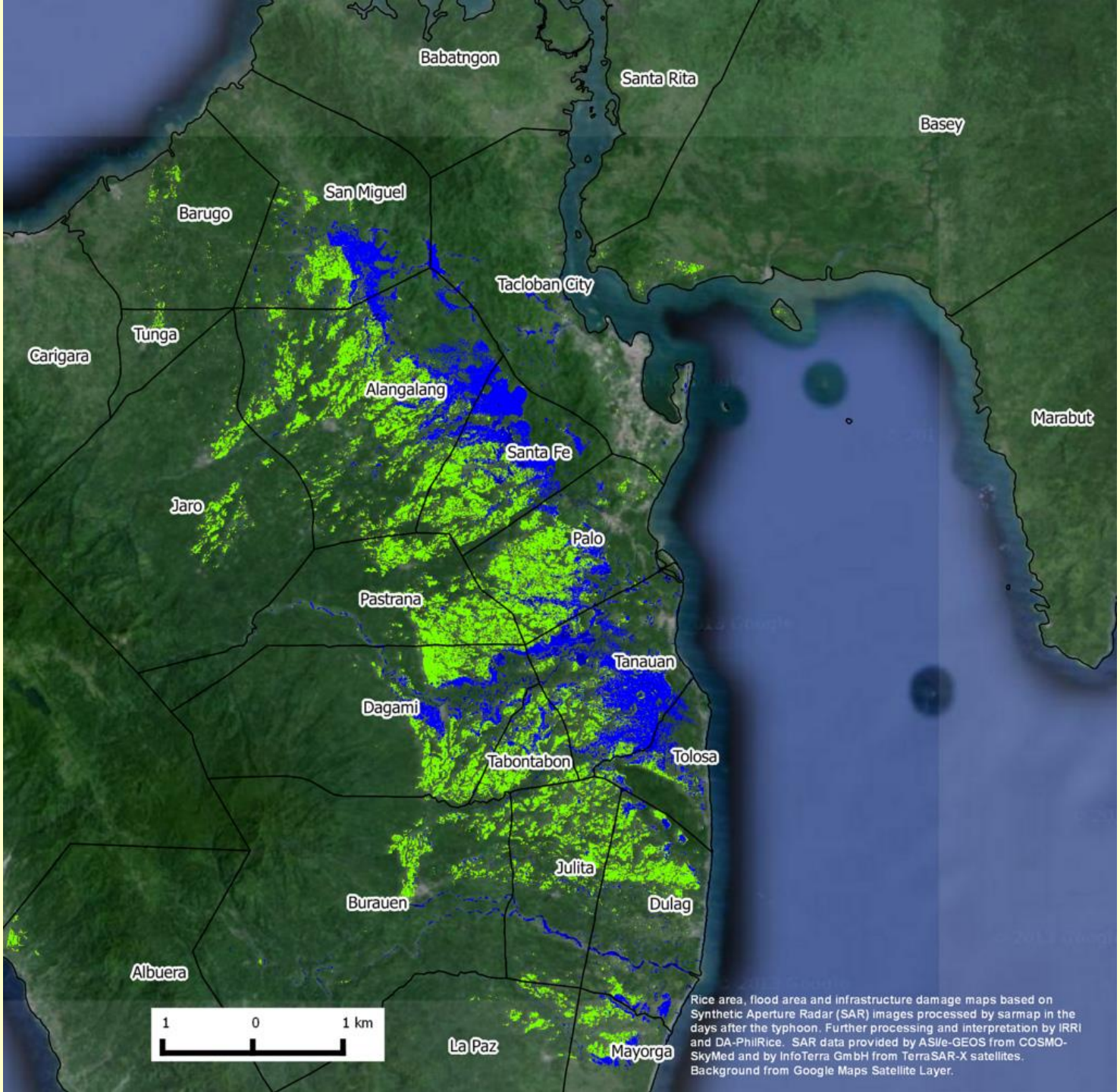

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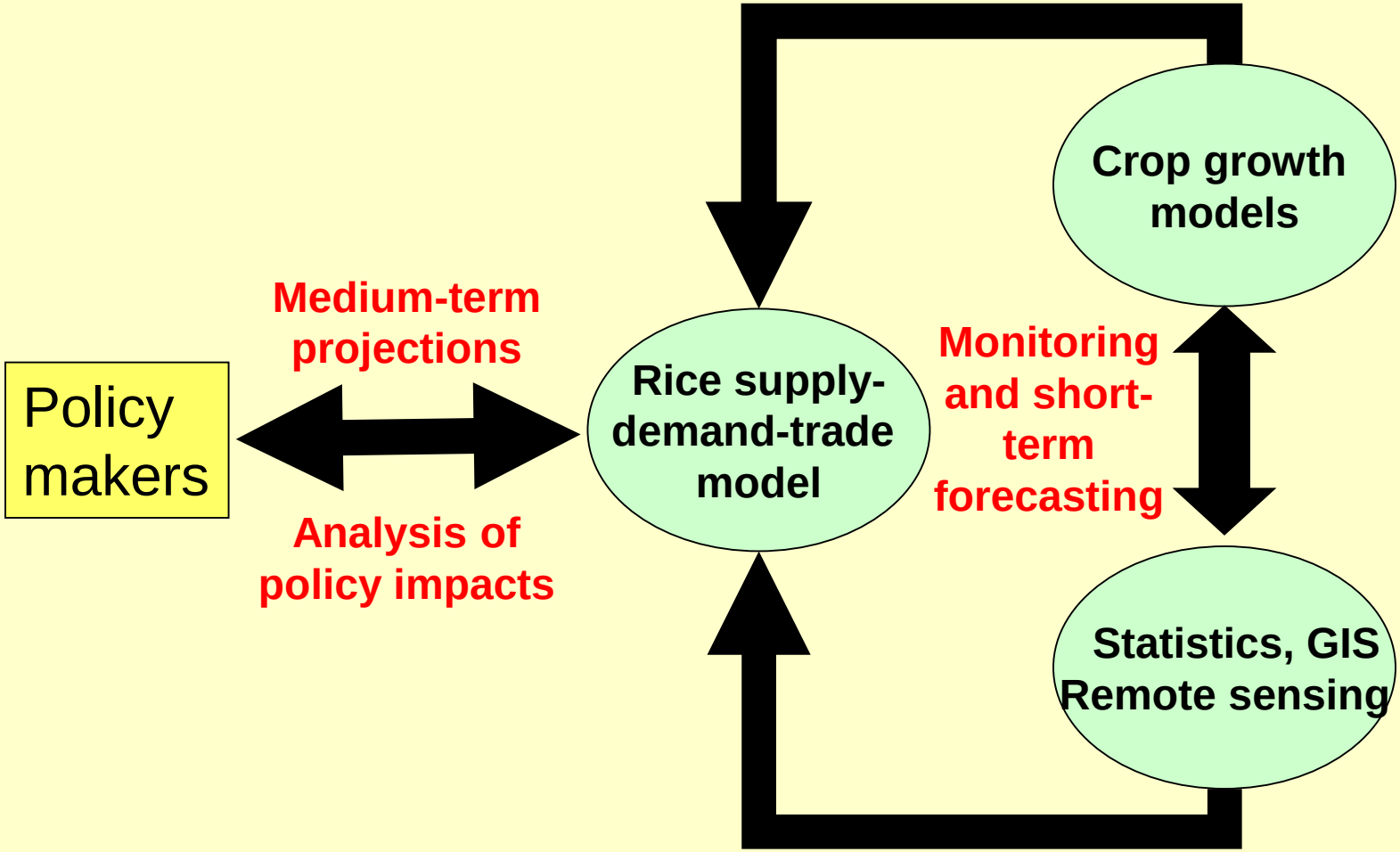
National/Global Rice Information Gateways



We Are Faced With…

- Surge of new technologies and potential technologies to benefit changing rice community
  - The way rice will be grown and marketed to meet demand in a changing climate…
- Surge in the demand for these technologies
  - How best to reach diverse rice farmers
  - Transformational interest of private sector in the rice sector
- **Increased risks of catastrophic losses**
- Need for pre-disaster mitigation tools

IRRI

"Precious things are not pearls and jade
but the five grains…,
of which rice is the finest"

- Ancient Chinese saying

Rice Science for a Better World

THANK YOU

IRRI

Help us fill the world's rice bowls

Come join us!

http://irri.org/JoinUs

Rice Science for a Better World

FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Agrilinks
AGRICULTURE SECTOR COUNCIL

Thank you for joining us!

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You can also visit the event page to post comments & questions.

Stay In Touch

Contact Us:
agrilinks@agrilinks.org

OR

Julie MacCartee,
USAID/BFS
jmaccartee@usaid.gov

Upcoming Events

Webinar | Emergency Seed Systems | Oct 9

Ag Sector Council | Smallholders to Shareholders
July 28 – Aug 1

Agrilinks and the AG Sector Council Seminar Series are products of the USAID Bureau for Food Security under the Feed the Future Knowledge-Driven Agricultural Development (KDAD) project.