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Cutting – Edge Rice Science for Food Security, Economic Growth and Environmental Protection

CGIAR Research Program on Rice Global Rice Science Partnership

R. S. Zeigler
Director General

International Rice Research Institute

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, > 70% of poor)

- And it grows under monsoon conditions where no other major crops can grow

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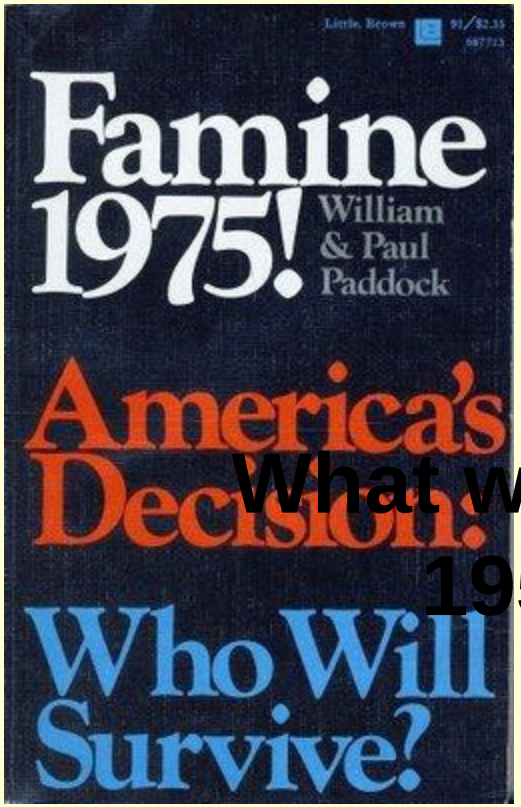
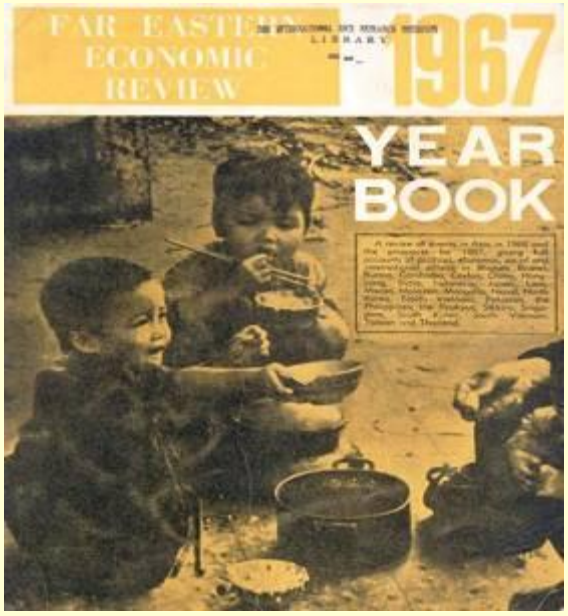


What was the world view in 1950s and 1960s?



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Global Rice Science Partnership

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

The Green Revolution in Asia

1960s

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

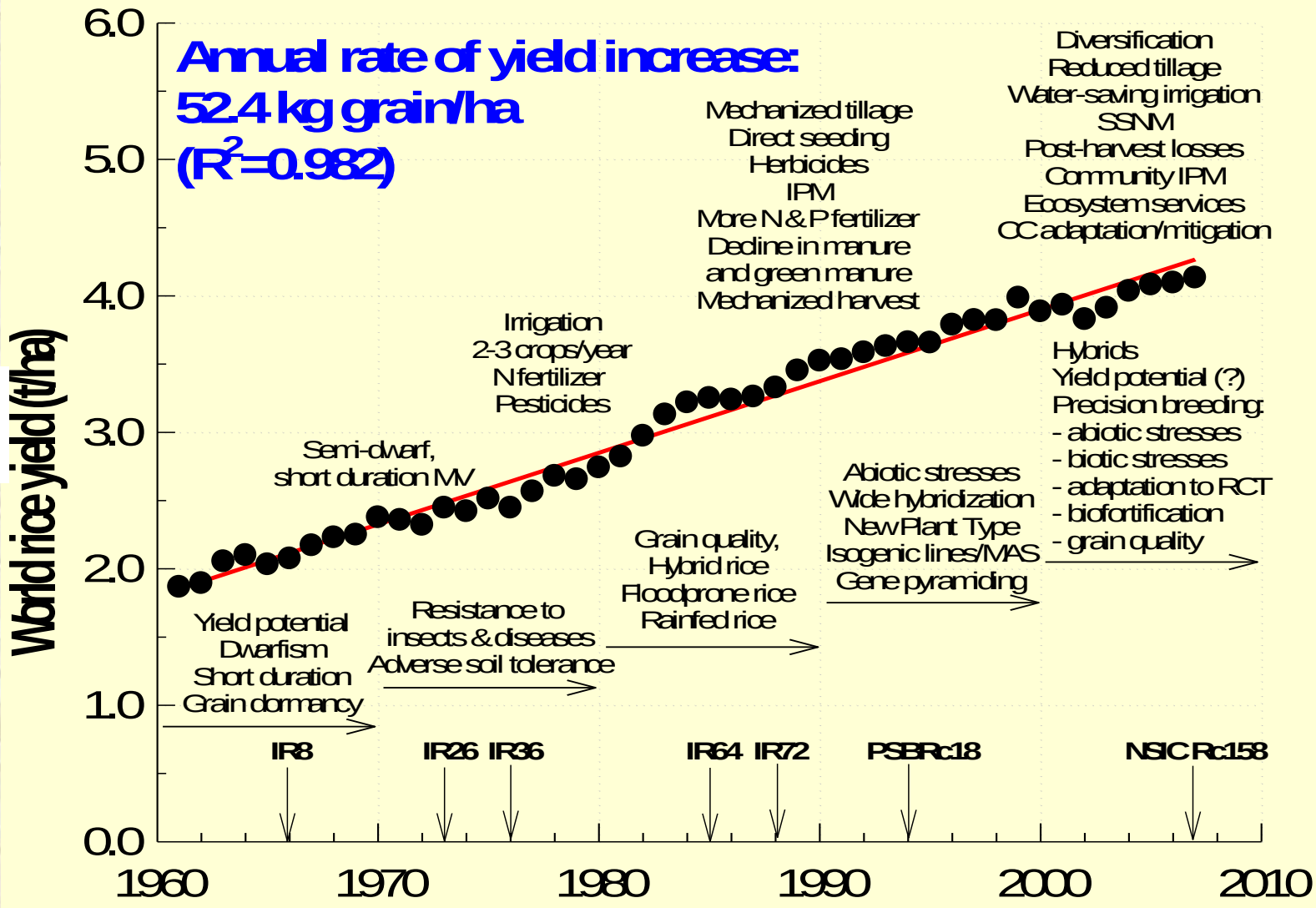
Today

- *yields ~4.5 t per ha*
- *economic growth*

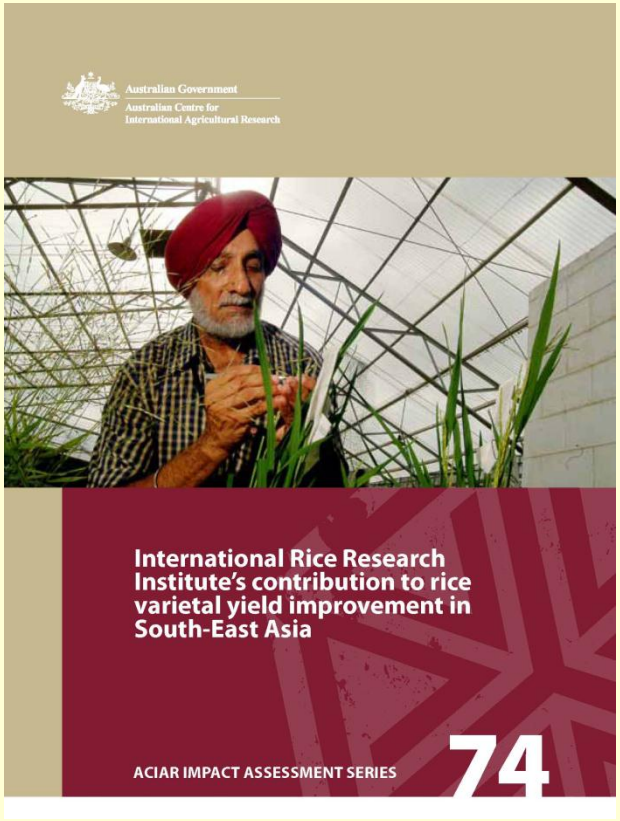
IR8 (semi-dwarf) launched the Green Revolution and saved millions from starvation

Science doing what people said could never be done

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


Annual rate of yield increase:
52.4 kg grain/ha
(R^2=0.982)
World rice yield (t/ha)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1960
1970
1980
1990
2000
2010
Yield potential
Dwarfism
Short duration
Grain dormancy
Resistance to
insects & diseases
Adverse soil tolerance
Semi-dwarf,
short duration MV
Irrigation
2-3 crops/year
N fertilizer
Pesticides
Grain quality,
Hybrid rice
Floodprone rice
Rainfed rice
Mechanized tillage
Direct seeding
Herbicides
IPM
More N & P fertilizer
Decline in manure
and green manure
Mechanized harvest
Abiotic stresses
Wide hybridization
New Plant Type
Isogenic lines/MAS
Gene pyramiding
Diversification
Reduced tillage
Water-saving irrigation
SSNM
Post-harvest losses
Community IPM
Ecosystem services
CC adaptation/mitigation
Hybrids
Yield potential (?)
Precision breeding:
- abiotic stresses
- biotic stresses
- adaptation to RCT
- biofortification
- grain quality
IR8
IR26
IR36
IR64
IR72
PSBRc18
NSIC Rc158

ACIAR Impact Assessment



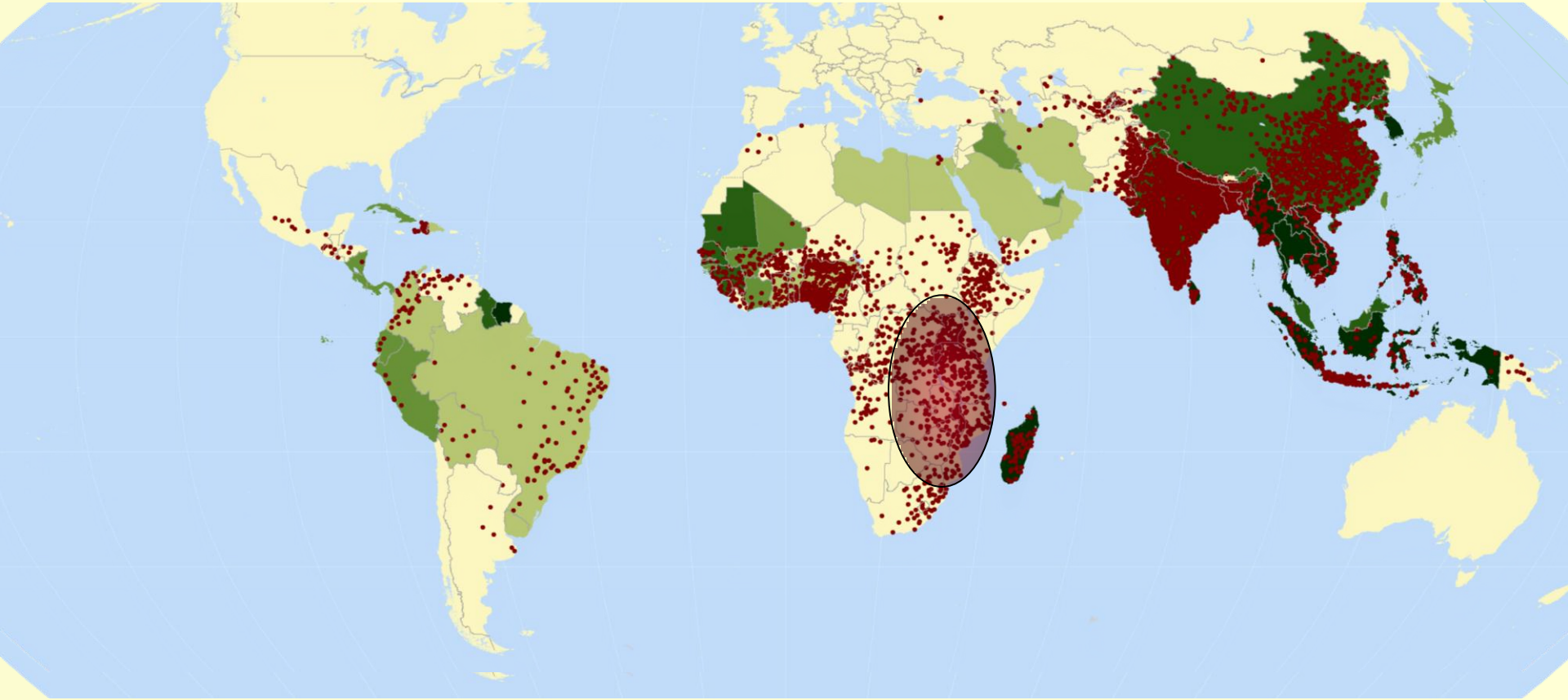
- **ACIAR 2011 impact assessment of IRRI's rice breeding**
  - **Vietnam, Indonesia, Philippines**
- **$1.46 billion *per year* from 1985 - 2009**

"This means farmers are now harvesting more rice per hectare, which not only lifts them out of poverty, but contributes toward the worldwide challenge of feeding the estimated global population of 9 billion people in 2050," **Minister for Foreign Affairs Kevin Rudd** September 2011.

Rice: The Global Staple

- **Staple food for more than half of humanity**
  - **Primary staple for >2/3 of the world's poor**
  - **3.5 billion obtain ≥ 20% of calories from rice**
- **Consumption growth in Sub – Saharan Africa is fastest in the world (5%/yr)**
  - **Import ~ 40% of consumption from Asia**
- **Most important staple of the poorest segments of Latin America**
  - **Fastest rate of growth among all staples (2%/yr)**

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



Rice Consumption

Annual consumption per capita

<25kg 25-50 50-75 75-100 >100kg

Poverty

Each dot represents 250,000 people living on less than $1.25 a day, 2005

Over 70% of the world's poor are in Asia

90% of the world's rice is produced and consumed in Asia

The face of poverty

The c… f… poverty…
Hu… …trition

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CGIAR

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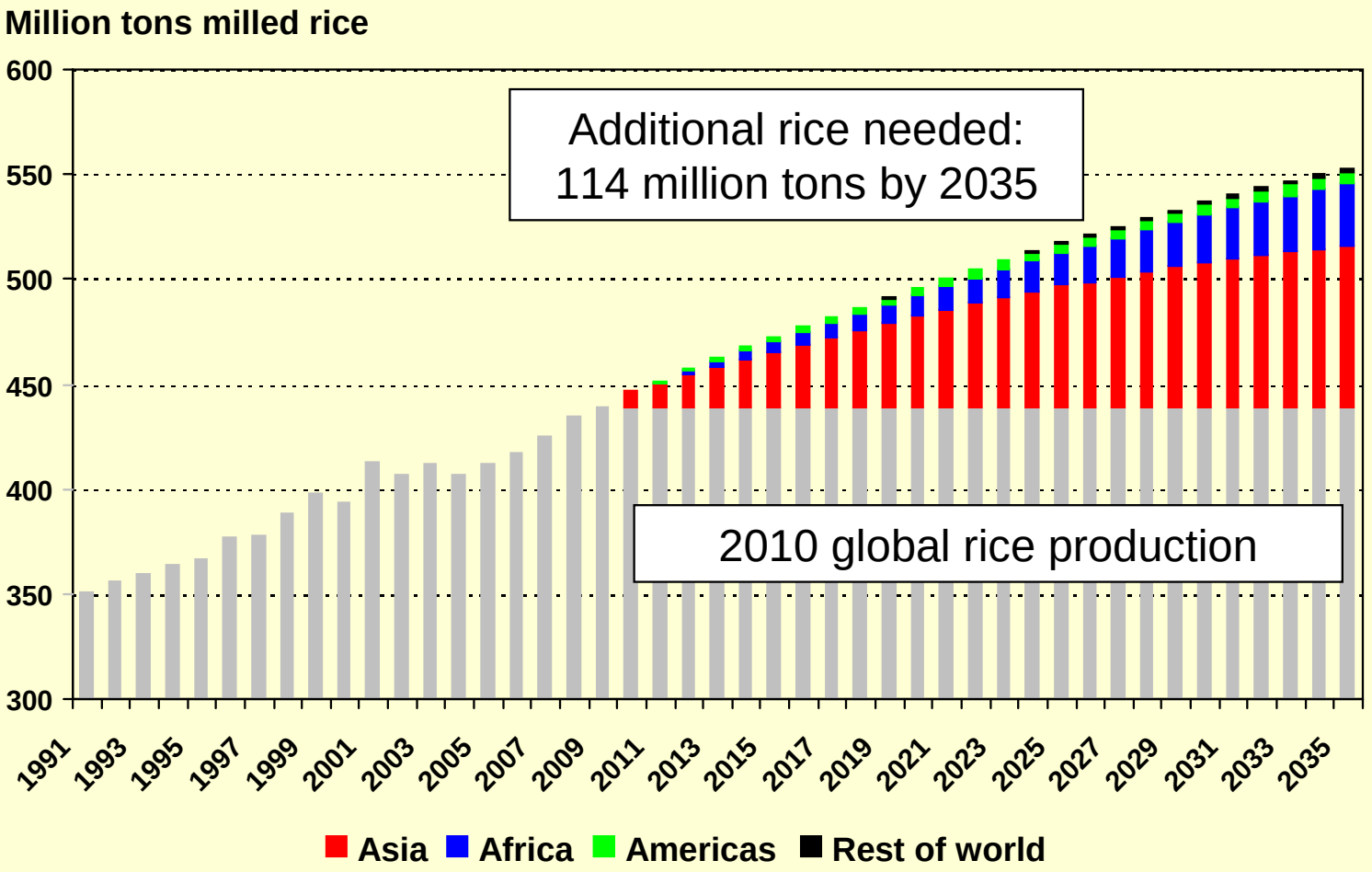
Rice is typically grown by small family farm enterprises (<2 ha)

And most rice farm labor is by women and children…

Will (should) this be the way of the future?

Global rice production increases needed to meet demand by 2035

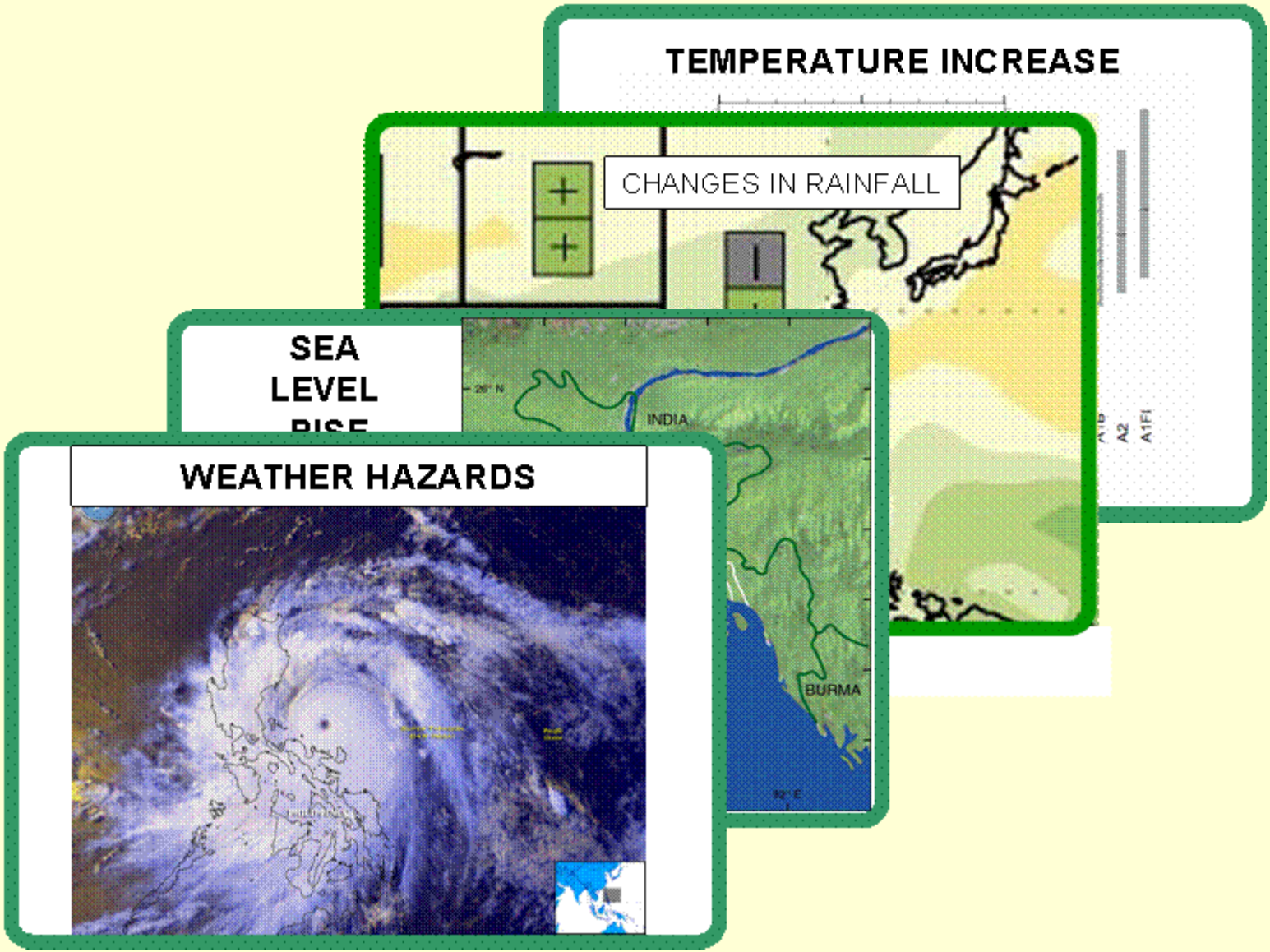
Where Will the World's Rice Come From?



Where Will the World's Rice Come From?

- **Ideally from increasing productivity on existing rice lands, mostly in Asia**
- **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***
- **Significant new rice lands may be needed**

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



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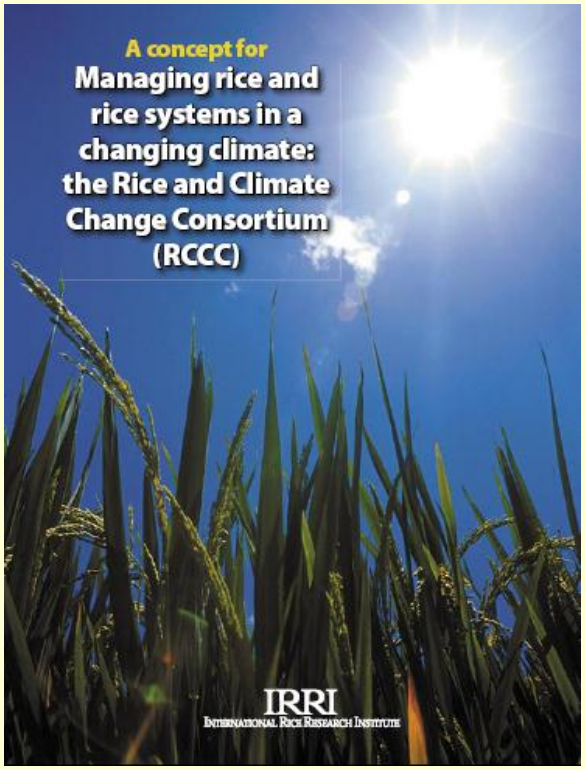
Climate and Rice



- **Global climate change will affect rice farmers for decades to come.**
  - ***Rising temperatures can negatively affect yield. (+1 ° C = 10% yield drop!)***
  - ***Extreme environmental events can increase frequency of drought, flooding, and sea water intrusion.***
- **Changing rice production systems will change GHG emissions from rice fields**

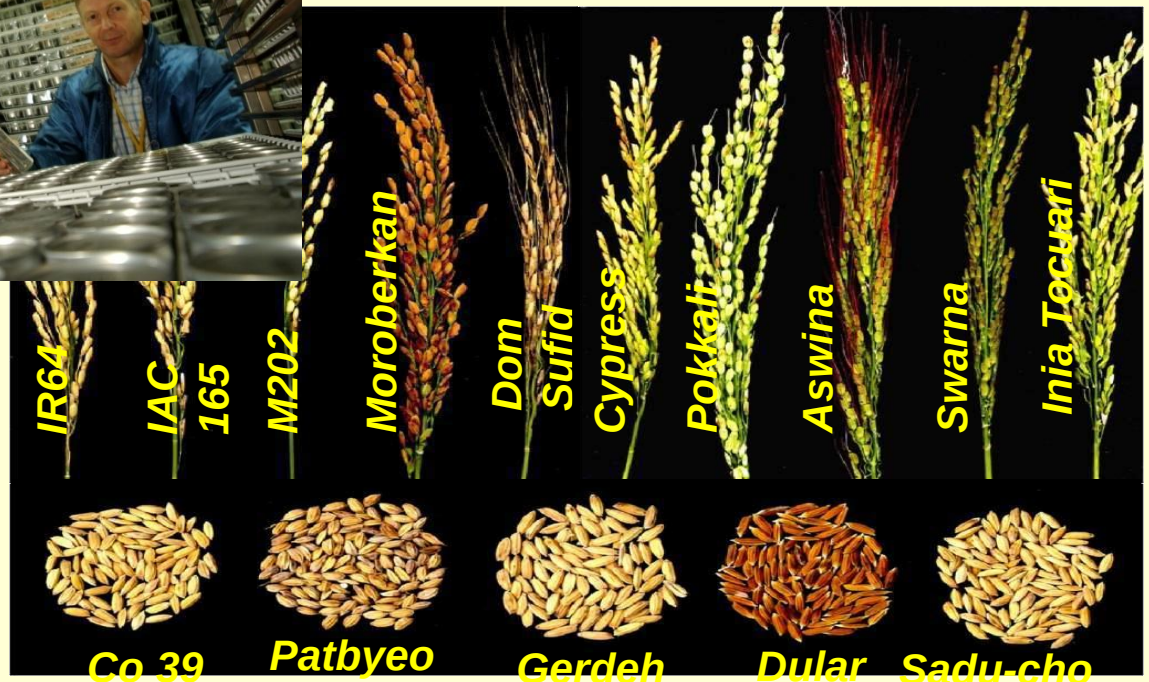
There is a clear and important role for developing rice varieties and management practices that can cope with climate change.

In the Future Climate the World Needs

- Rice varieties that
  - Tolerate higher temperatures
  - Survive prolonged flooding
  - Tolerate drought
  - Tolerate soil salinity
- Production practices that
  - Require less water
  - Use fertilizers more efficiently
  - Require less labor
- Systems that provide sustainable high yields

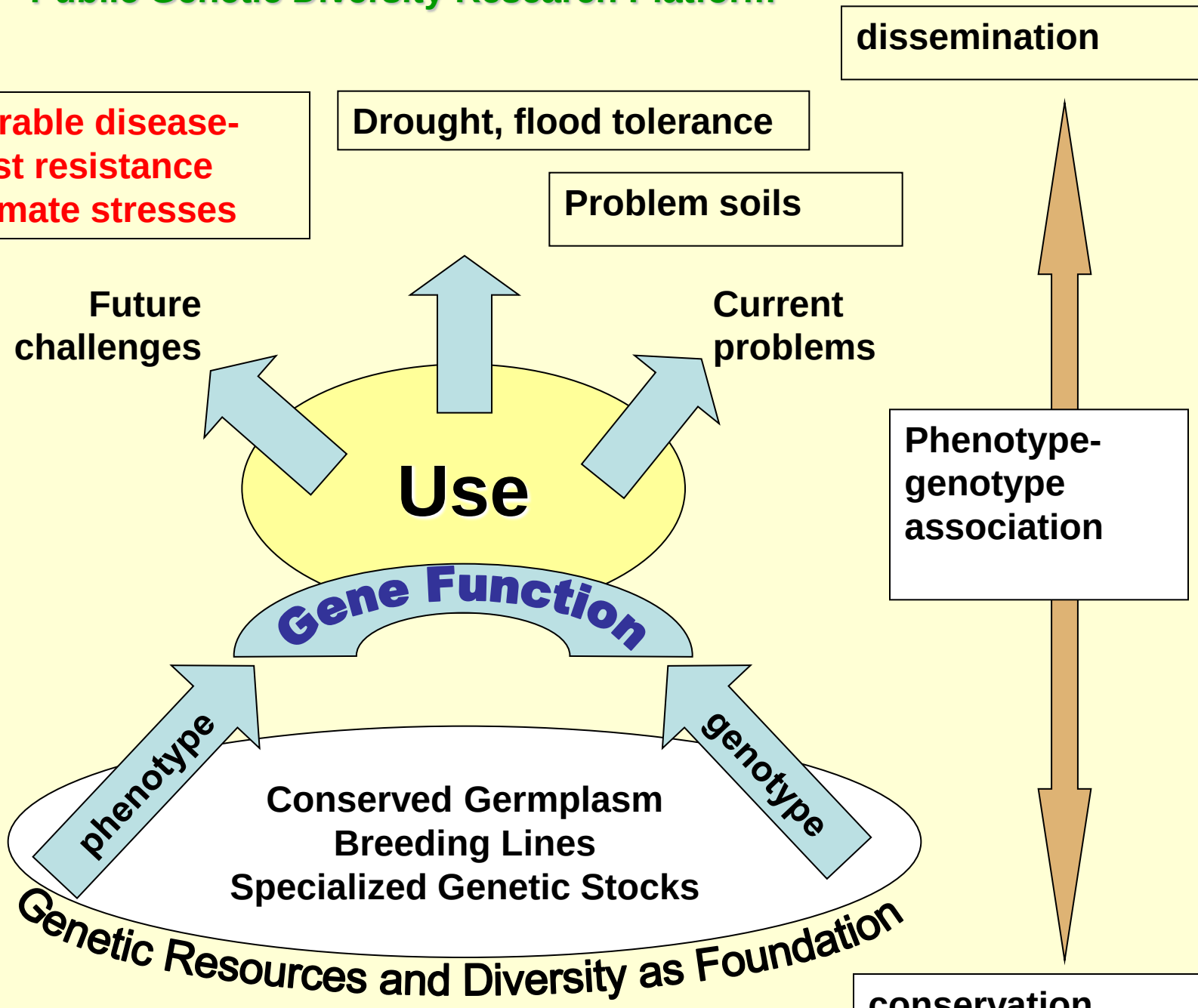
Cannot Overestimate Central Role of Germplasm for Coming Generations

Less than 5% used in rice Breeding programs



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

Public Genetic Diversity Research Platform



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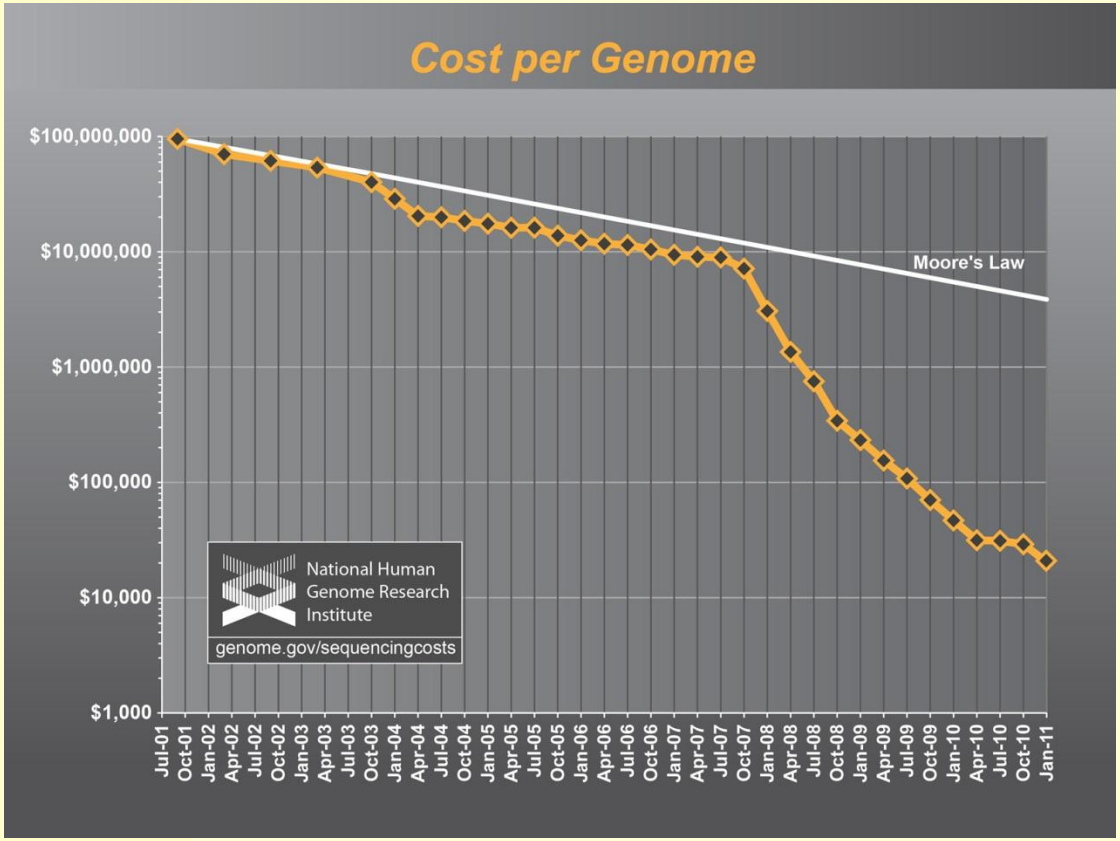
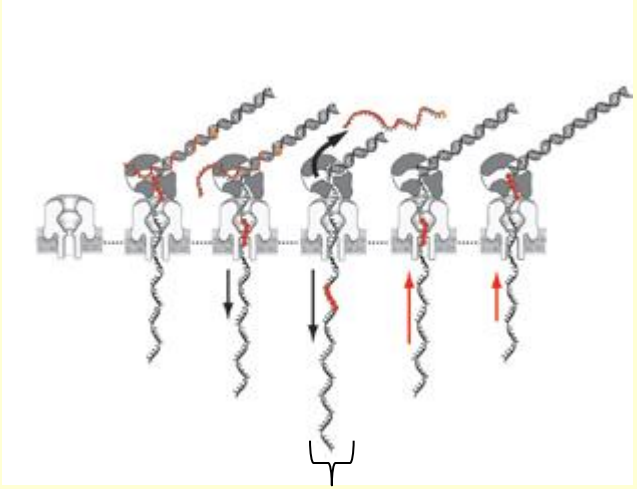
DNA Sequencing Costs Plummeting





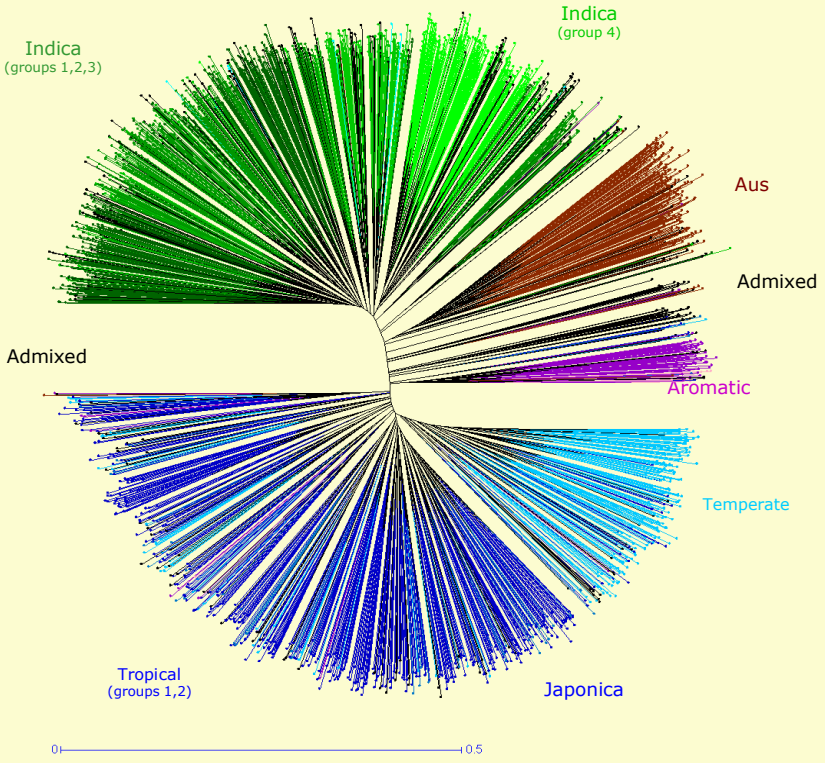
10^{-5} human hair

Nanopore Technology Will Lower Costs Even More

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**

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*

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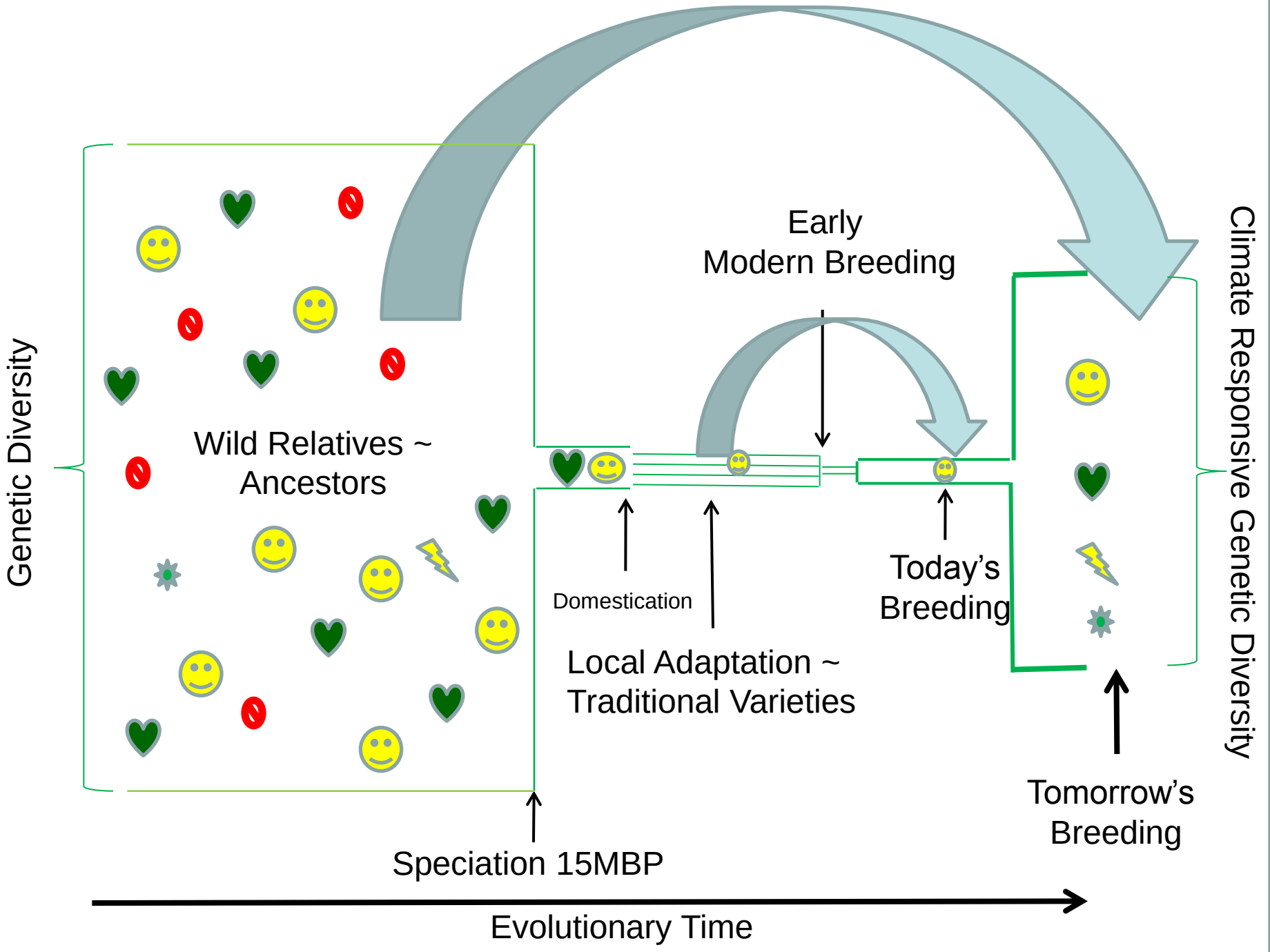
Genetic Diversity
Wild Relatives ~
Ancestors
Early
Modern Breeding
Domestication
Local Adaptation ~
Traditional Varieties
Today's
Breeding
Tomorrow's
Breeding
Climate Responsive Genetic Diversity
Speciation 15MBP
Evolutionary Time

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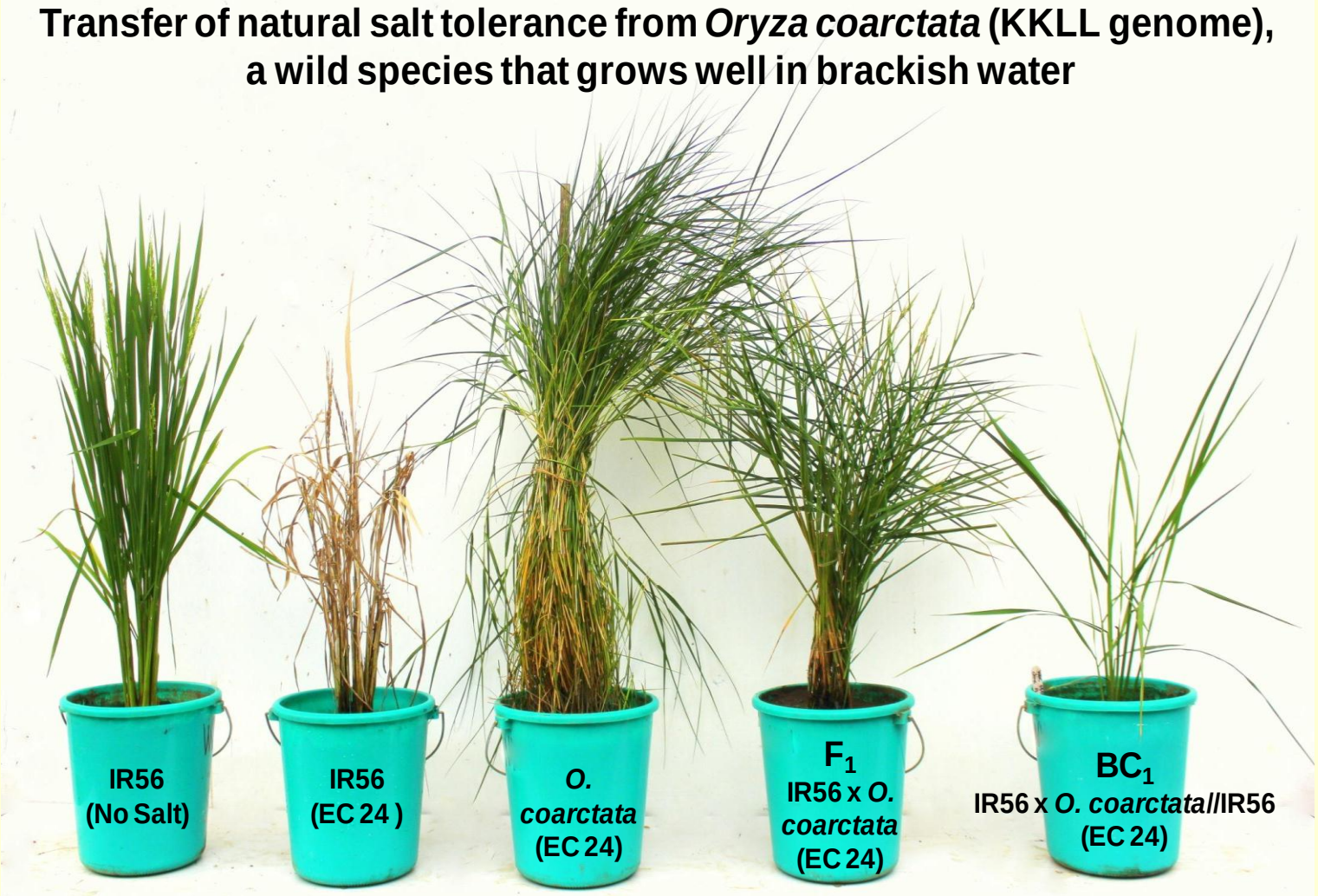
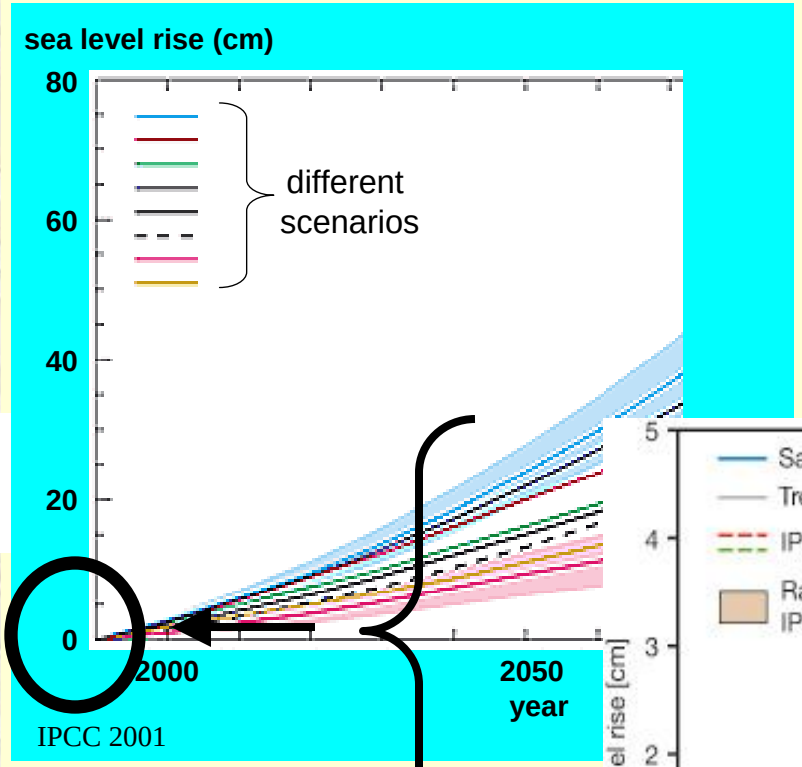
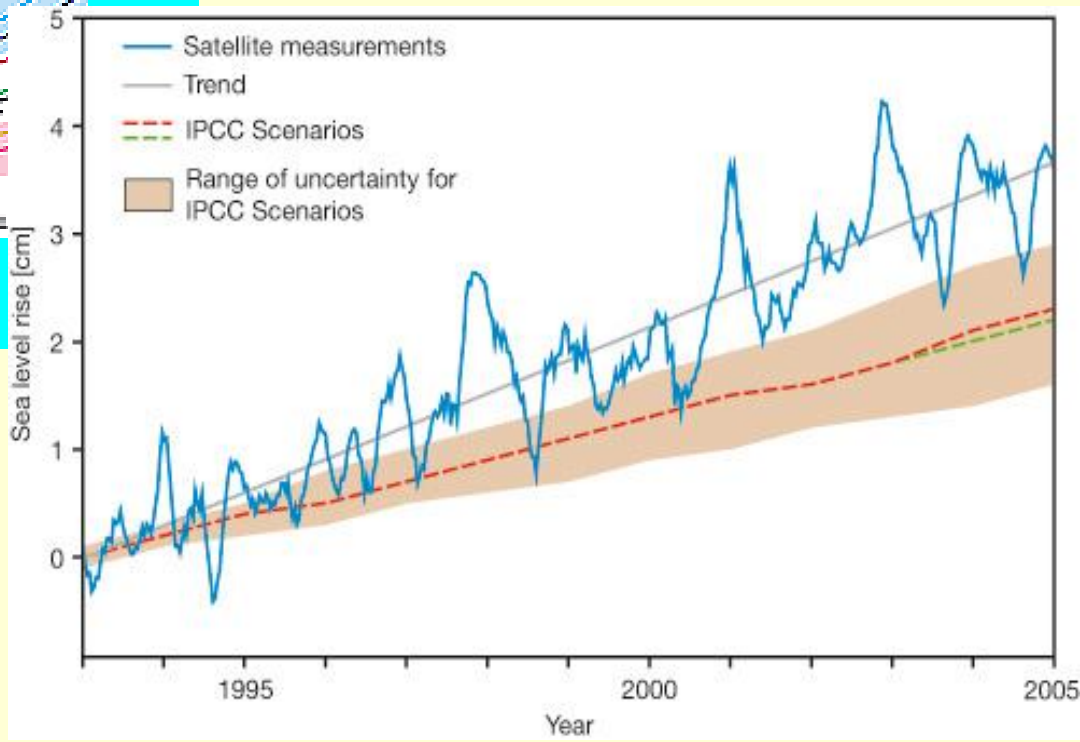
Transfer of natural salt tolerance from *Oryza coarctata* (KKLL genome), a wild species that grows well in brackish water



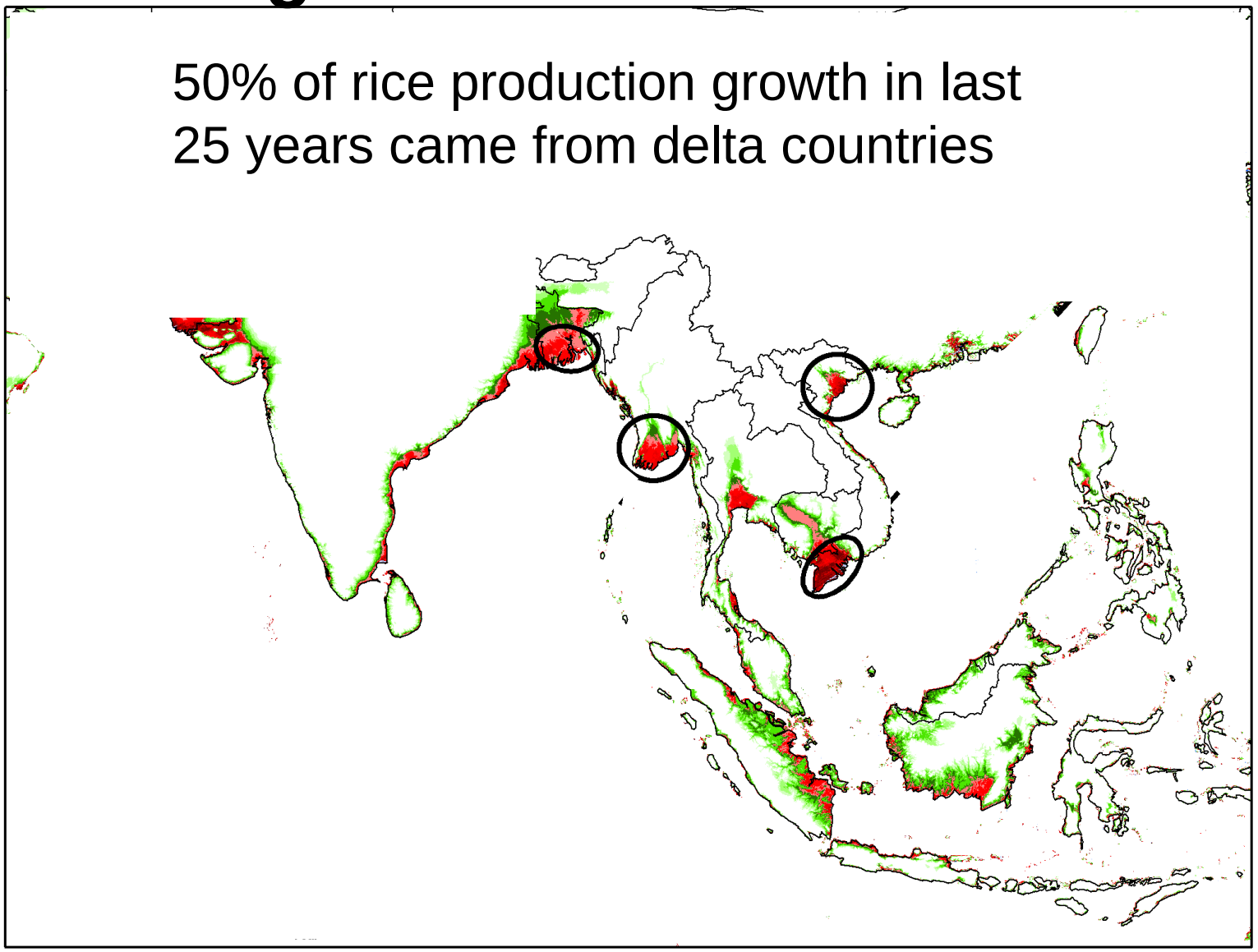
Sea level trends: The future





Mega-river deltas of Asia

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



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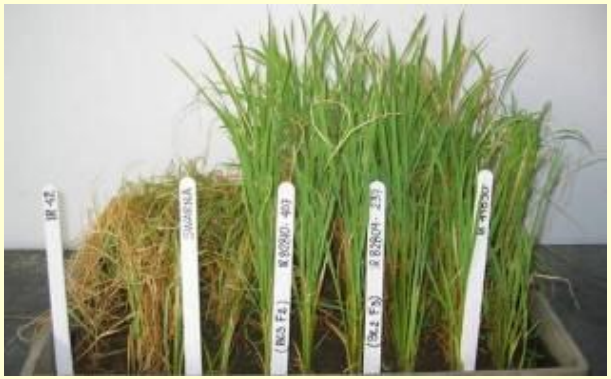
Breeding for submergence tolerance

- Large areas of rice have serious floods (eastern India to SE Asia); > 10 m ha per year
- Even favorable areas have short-term flooding problems in some years
- Flood tolerance identified in an Indian variety FR 13A
  - Poor agronomic and grain quality



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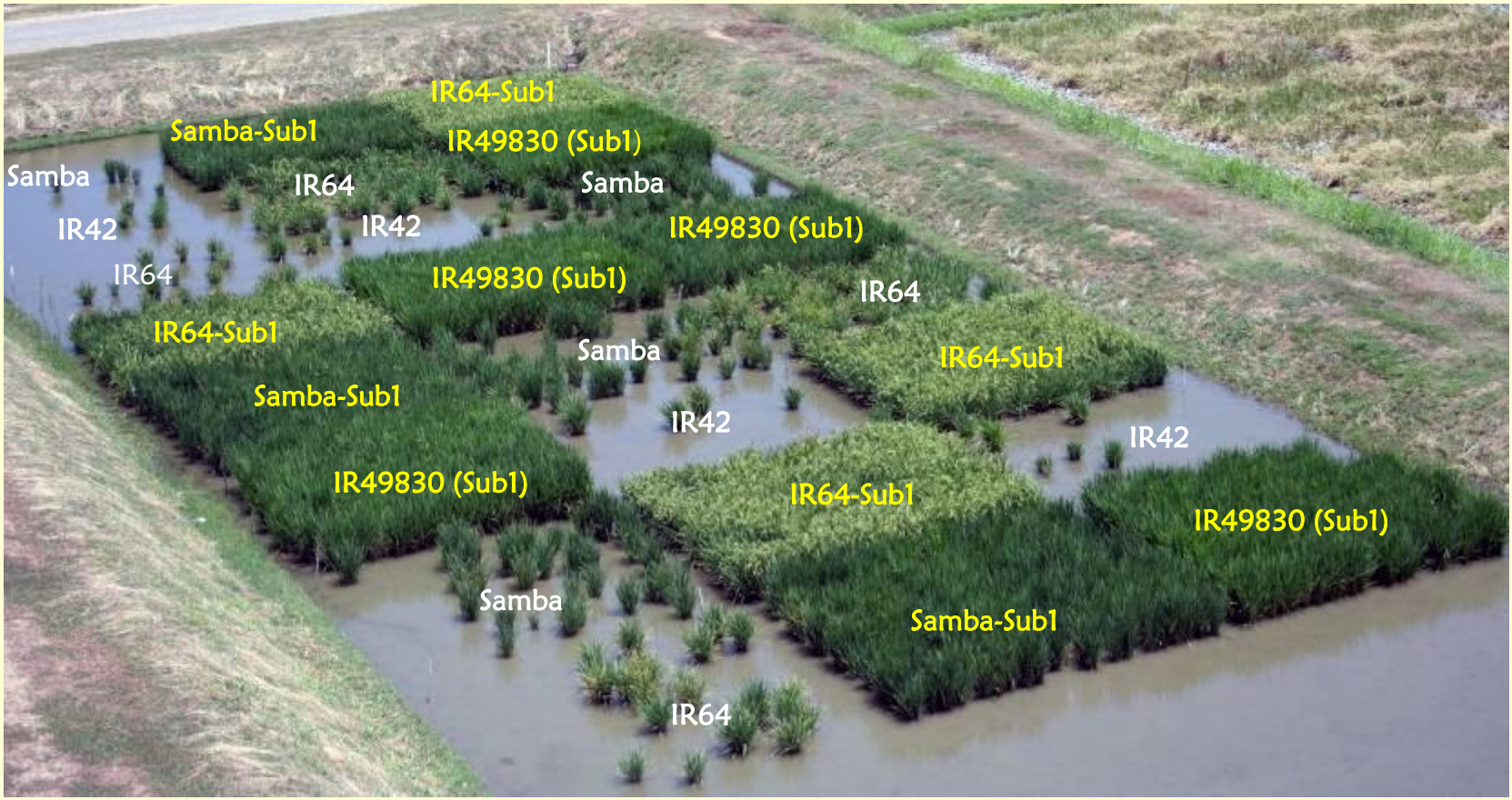
New *Sub1* lines after 17 days submergence in the field at IRRI



Genes for submergence tolerance moved into popular “mega-varieties”

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Sub1 varieties: help poor farmers to cope with perennial flooding

Eastern Uttar Pradesh

Major support from Japan USAID, B&MGF enables us to reach 3,000,000 farmers in 2012r…millions more over the next few years

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

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Sub1 varieties: help poor farmers to cope with perennial flooding

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

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Major support from Japan
USAID, B&MGF enables
us to reach > 3,000,000 farmers
In 2012…millions over
the next few years

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

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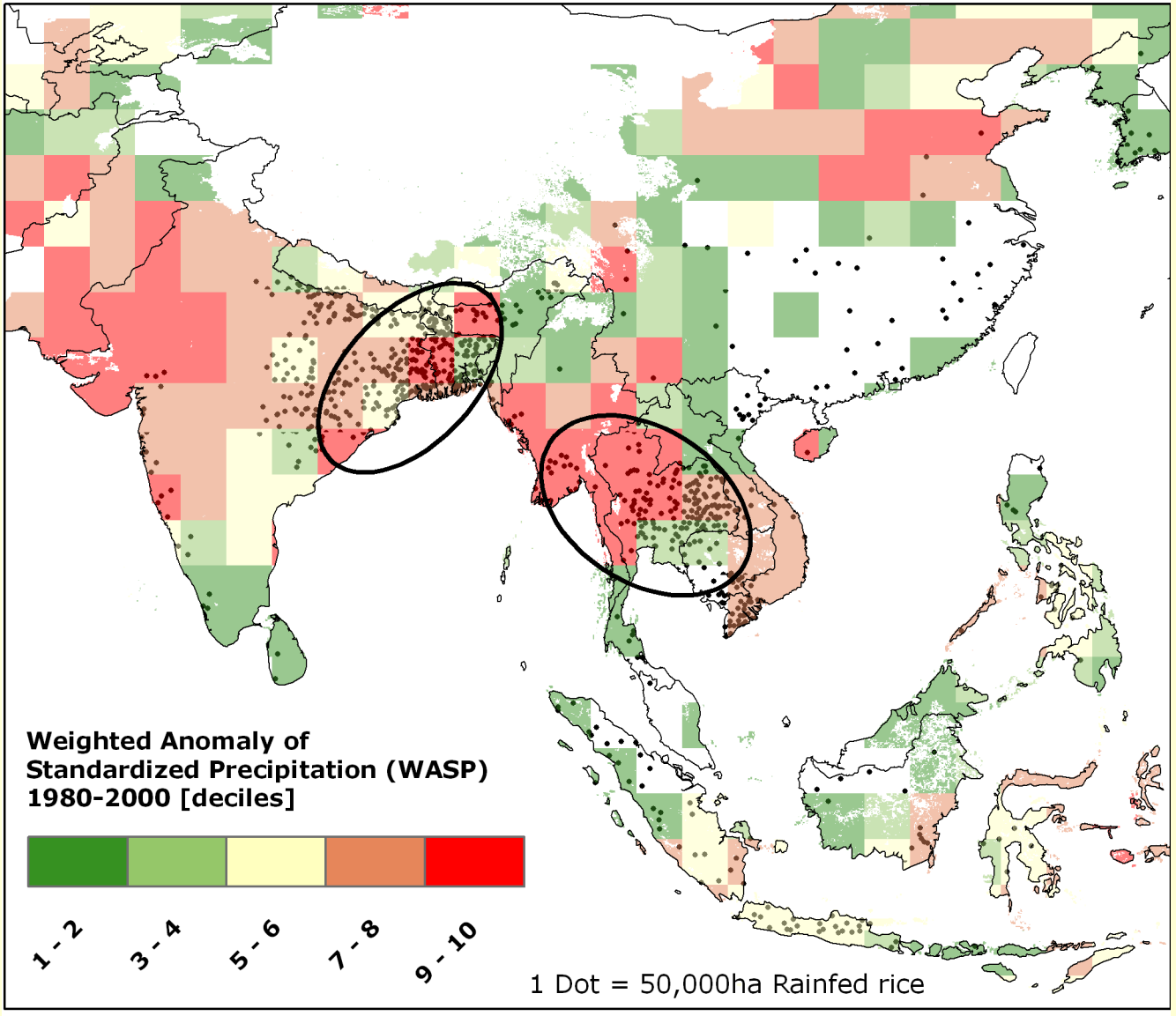
Variation in Rainfall = Risk of Drought



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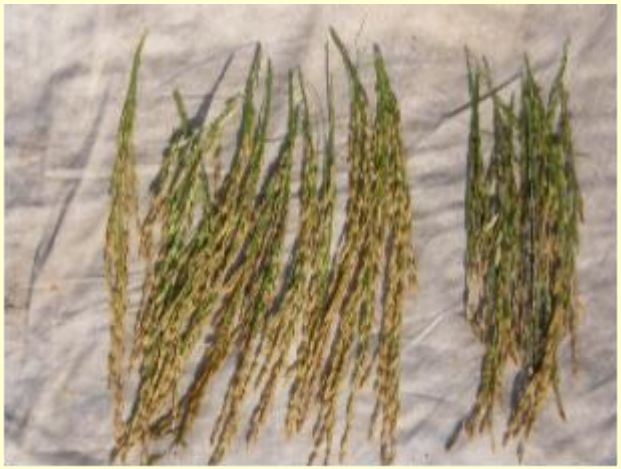
First generation drought tolerant rice varieties released in South Asia

- Farmers like the new drought tolerant varieties
- Buffalo like the straw… improved milk supply?
- Now combined drought tolerance with flood tolerance!

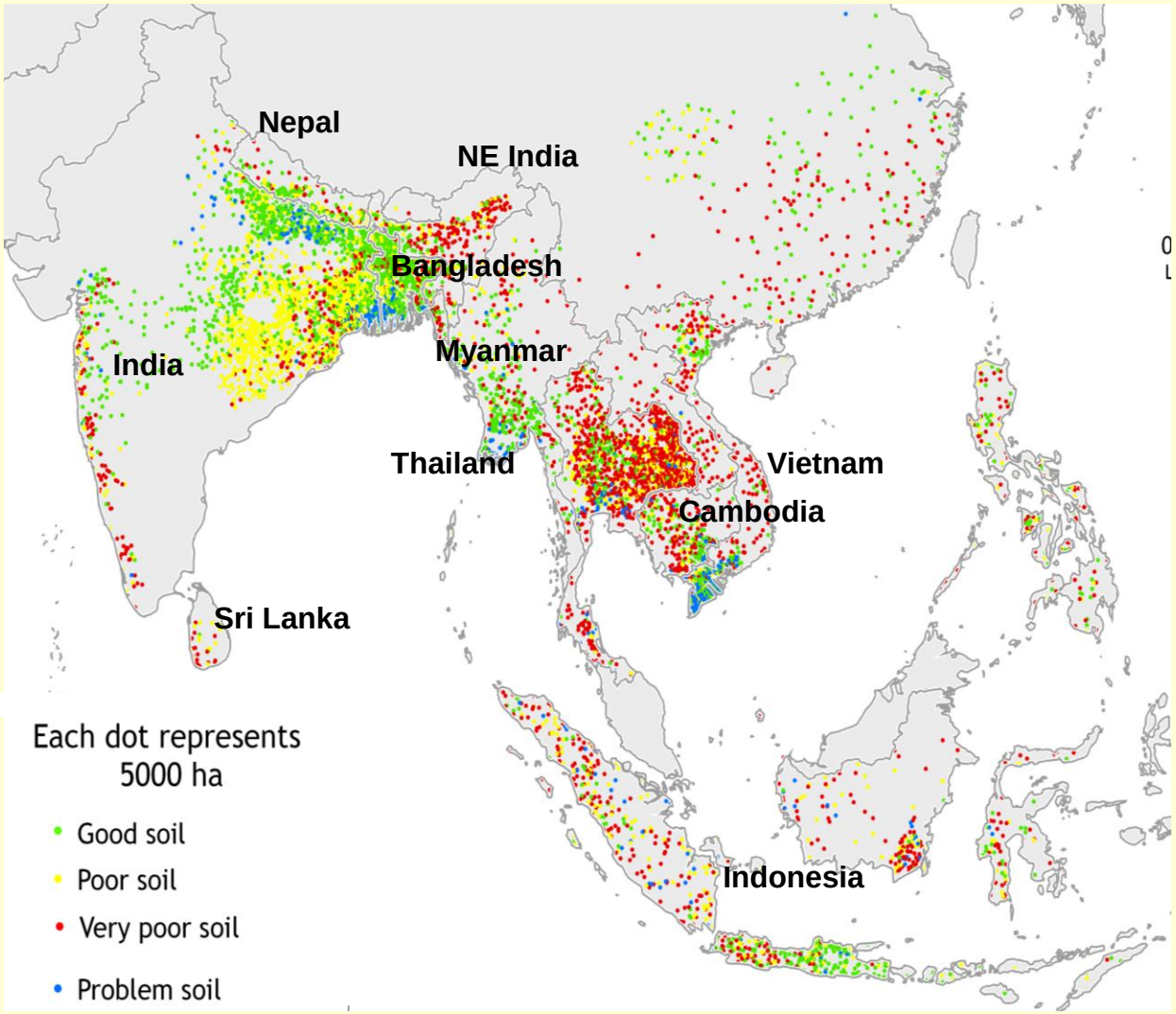
IR 64+ QTL IR 64 - QTL

Swarna with RM 520 and RM324 QTLs

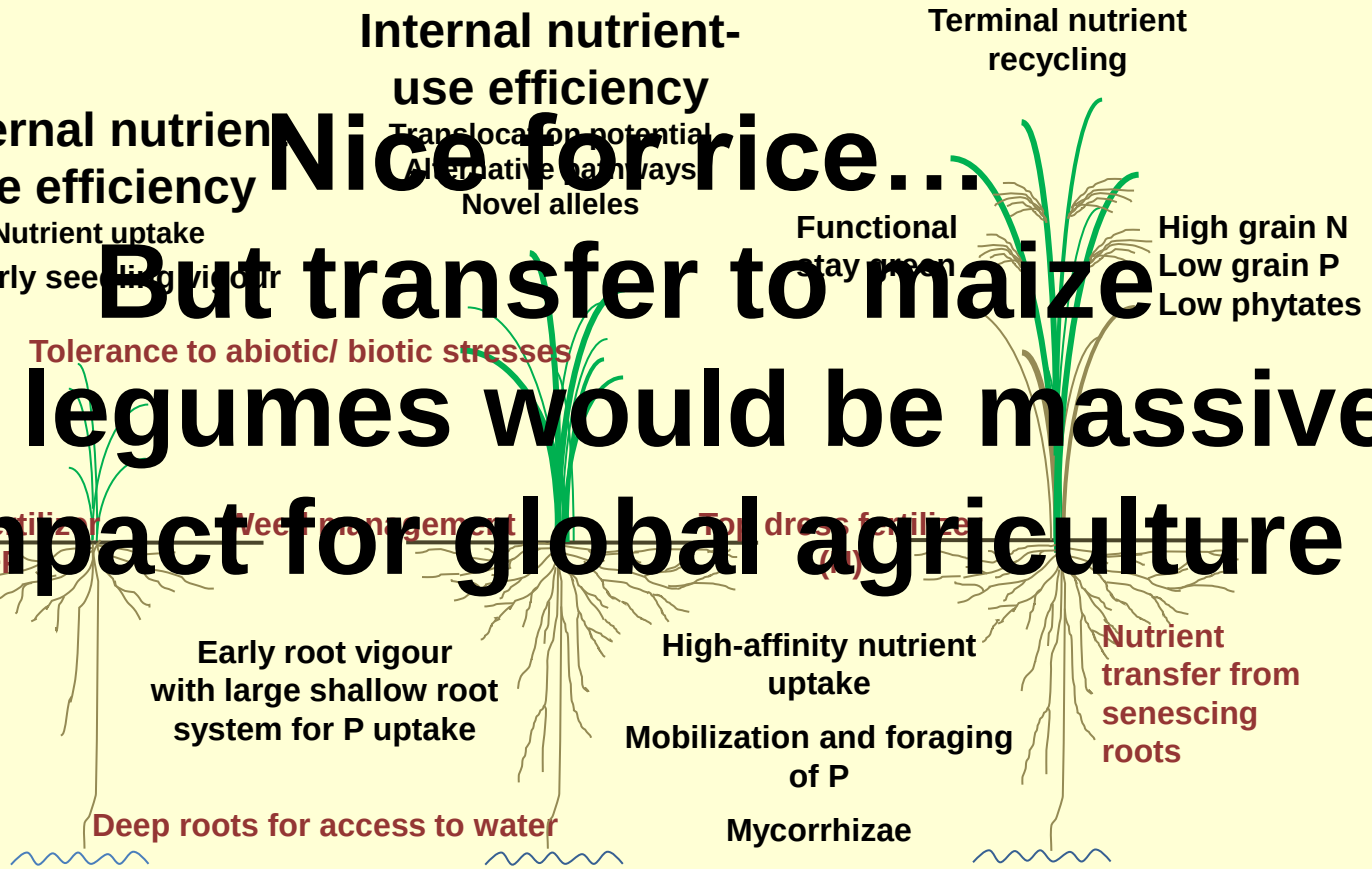


Source: A. Kumar, IRRI

Poor soils dominate rice areas



Phosphorus efficient gene linked to root development *Nature, Sept., 2012*



Nice for rice…

But transfer to maize or legumes would be massive Impact for global agriculture

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A CONVENIENT CONVERGENCE

Consequences of Climate Change :

Rice systems will experience more…

- **Drought**
- **Submergence**
- **Salinity**
- **Heat waves**

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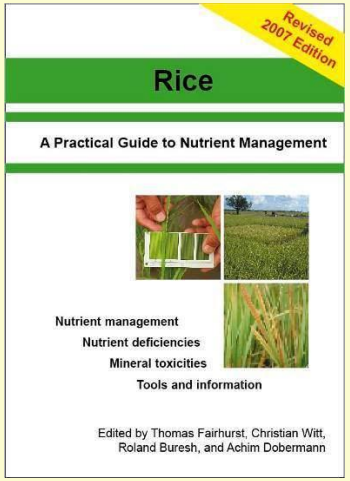
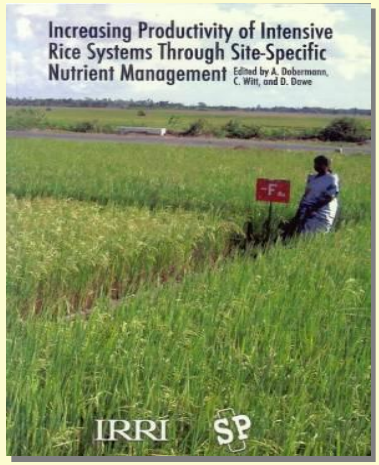
Challenges of Climate Change = Challenges faced today by the world's poorest rice farmers

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

Partnerships after 10 years (1996-2005)

Science is well documented





Tools are available for farmers

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

"Nutrient Manager" using interactive voice response (IVR): Precision farming on < 1 ha

GSM mobile phone

1. Call toll-free phone number with voice recording

IVR implementation box

2. Select a local language
3. Answer 10 to 12 questions with key pad to obtain farm profile
4. Complete in about 8 minutes
5. Transmit answers to model on high-end (cloud based) server
6. Generate advice specific to farmer situation

7. Deliver customized advice as SMS message

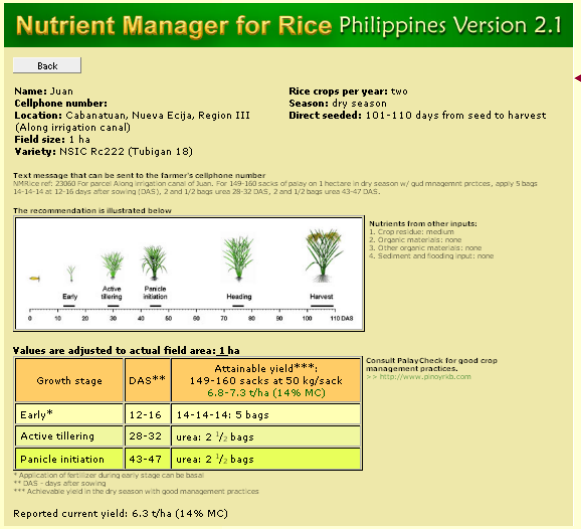
Web

Smartphone

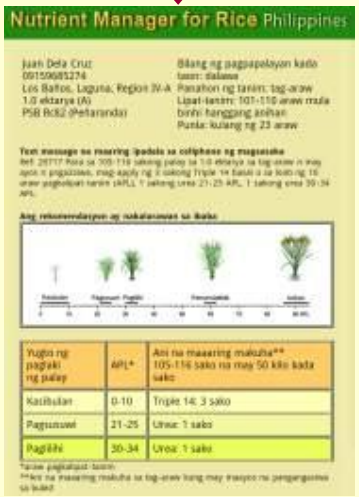
GSM mobile phone

Farmer calls 2378 using Globe SIM

Interactive Voice Response implementation box



Web output

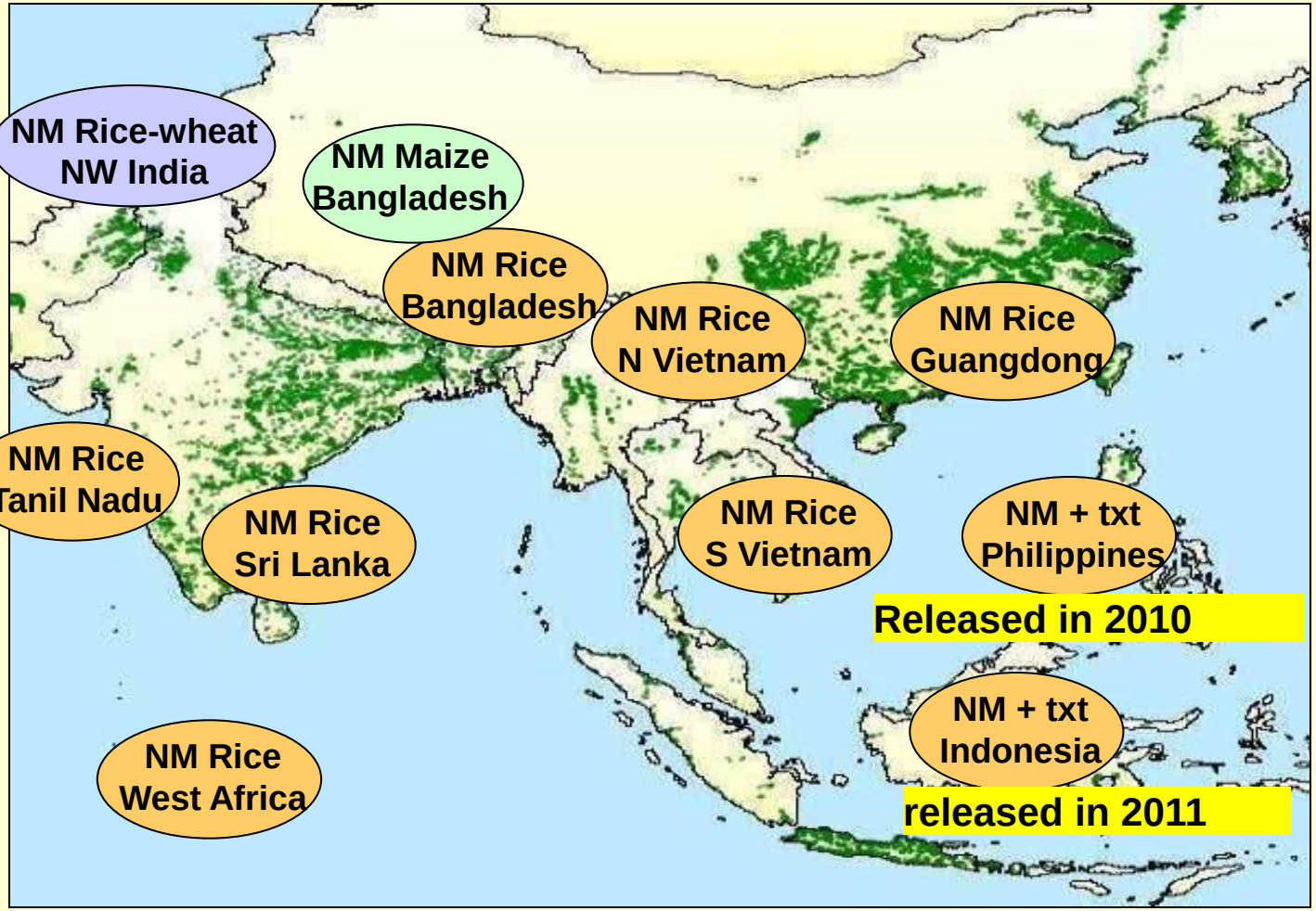


Smartphone output

SMS output

Converting to HTML 5

Nutrient Manager released or under development across Asia…Africa



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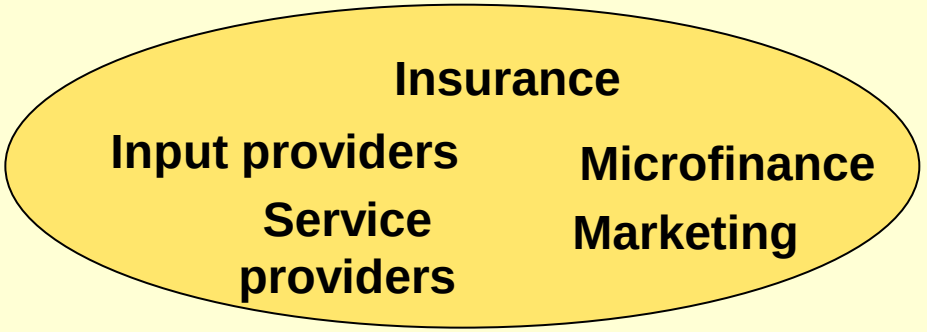
Connect farmers with relevant agricultural science and services

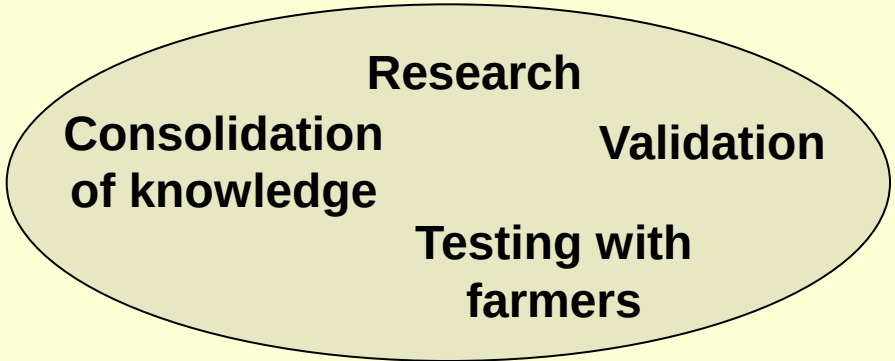
Suite of compelling services and financial products



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



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Relentless Pressure to Increase Rice Supplies is *NOW*

- Move to hybrid rice
  - In its infancy…very narrow genetic base
- Pressure from governments to produce 3 crops per year on the same plost
  - Build up of inouculm
- Pressure to squeeze higher yields
  - Greater fertilizer applications
  - More insecticides
- Pressure to use less water
  - Direct seeding, intermittent irrigation

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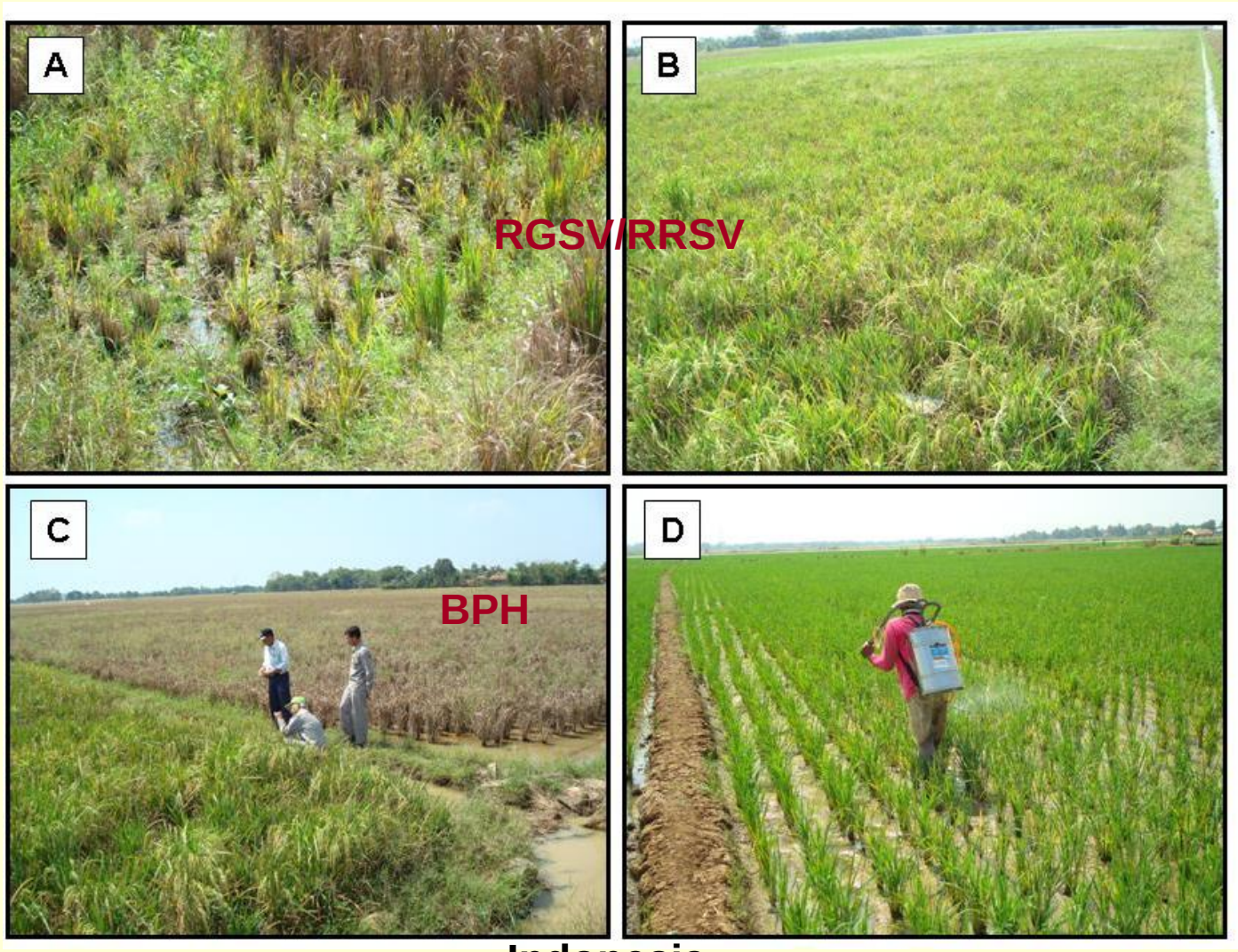
Planthopper and virus Outbreaks in Asia



Indonesia

Sustainable Rice Platform (SRP)

- To develop a set of *global standards for best practices* of sustainable rice production (global rice GAP)
- To develop quantifiable *sustainability targets*
- To develop and promote decision-support tools (such as Field or footprint Calculators)
- To promote the adoption of best practices and sustainability criteria

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

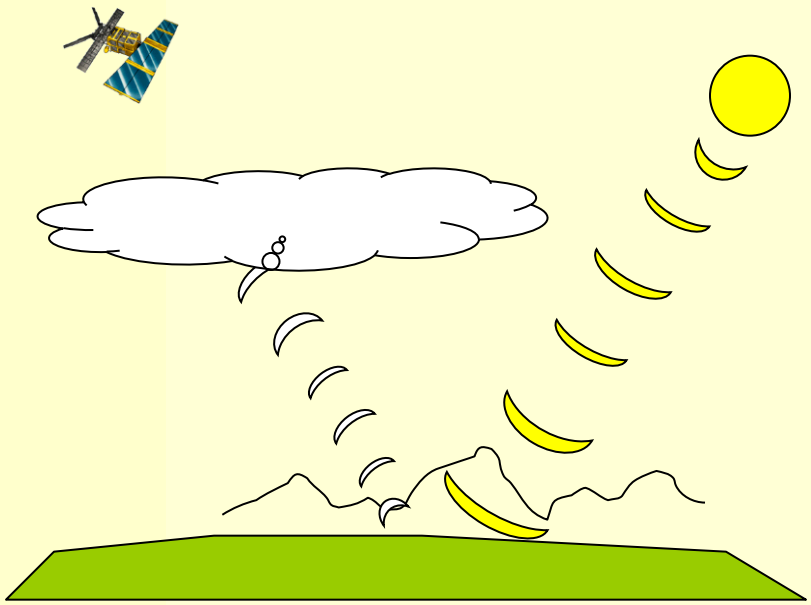
Location specific, timely and accurate information on rice production, supplies, and trends

In particular:

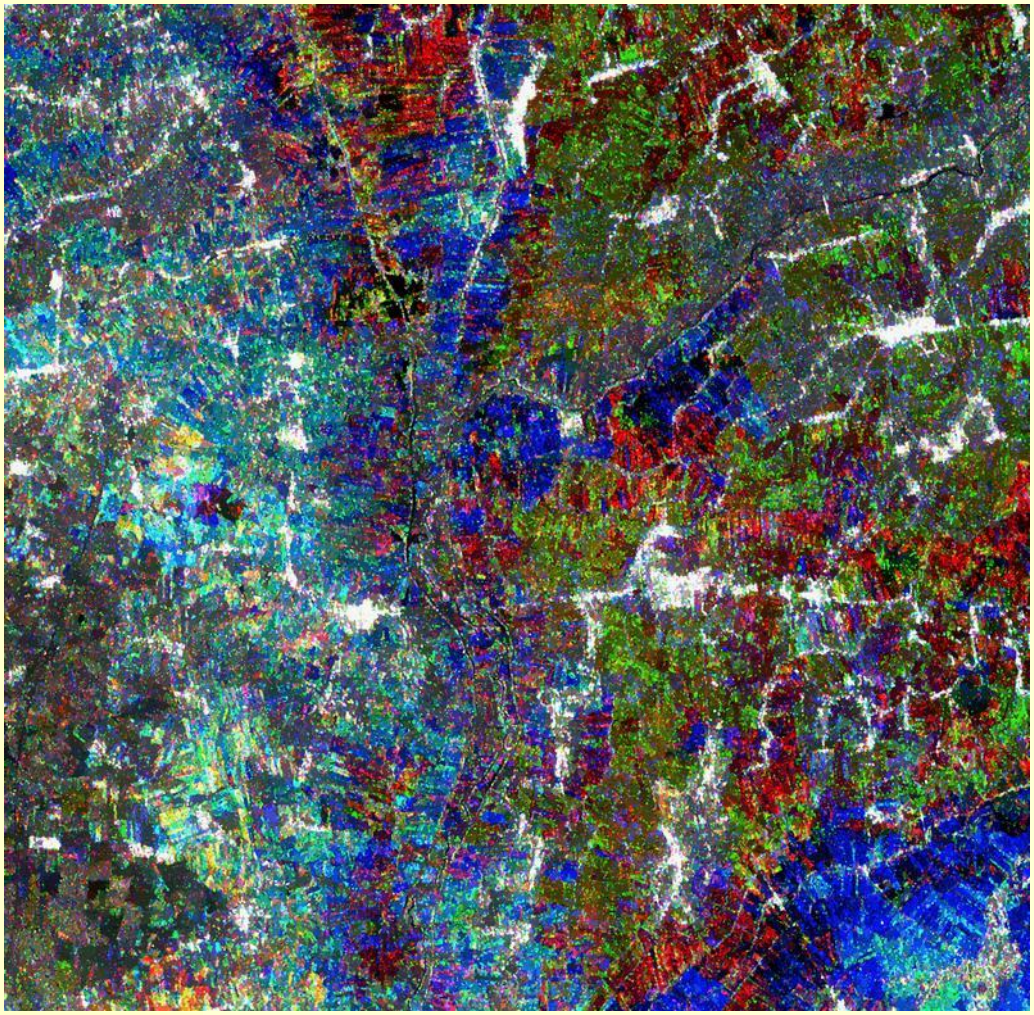
- What is the harvested area?
- When will it be harvested?
- What is the yield?

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

Optical



Radar-based real time crop monitoring system for rice



Color shows crop establishment

cyan late Dec to early Jan

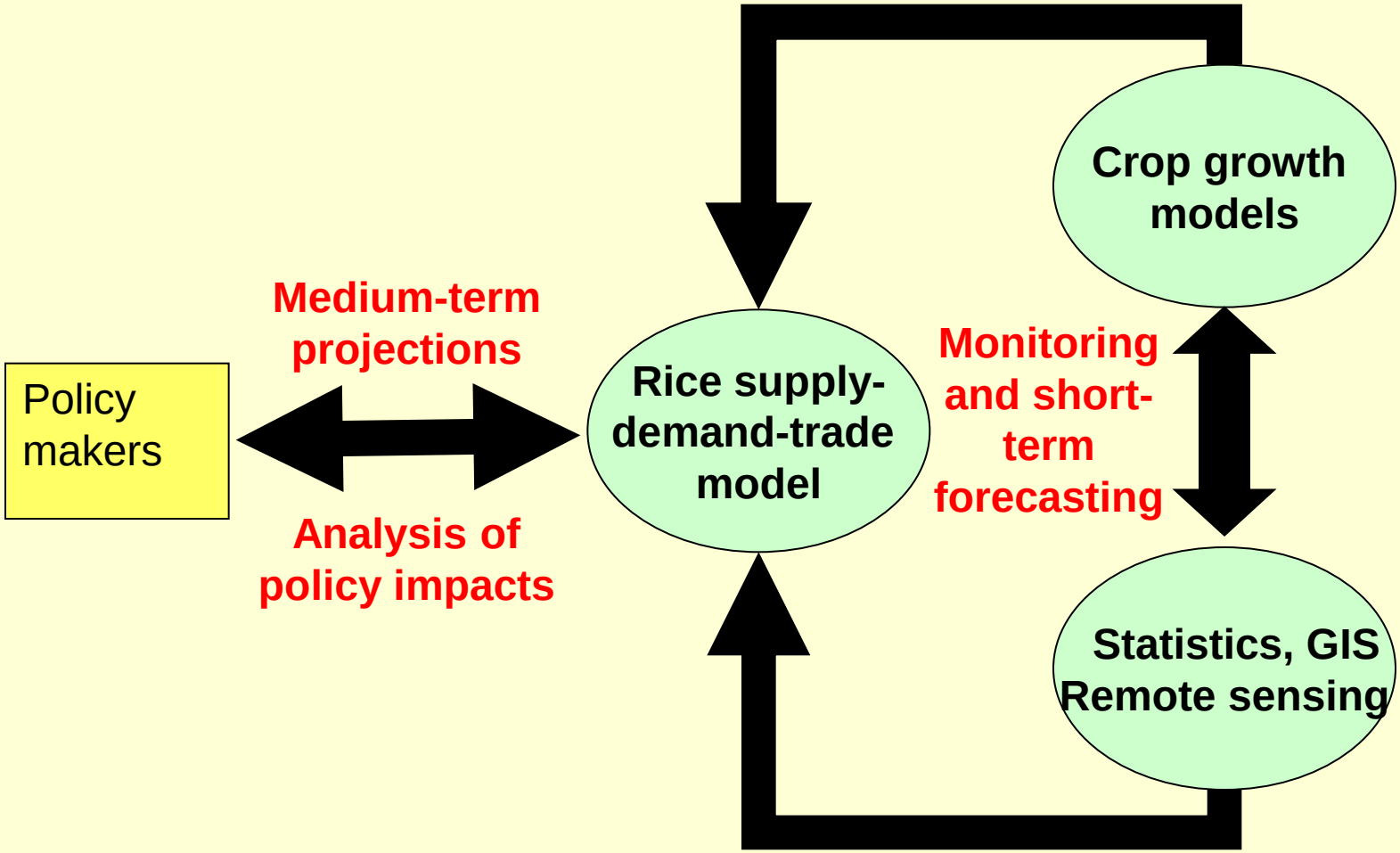
blue mid-Jan

red & **green** still under land preparation in mid-Jan

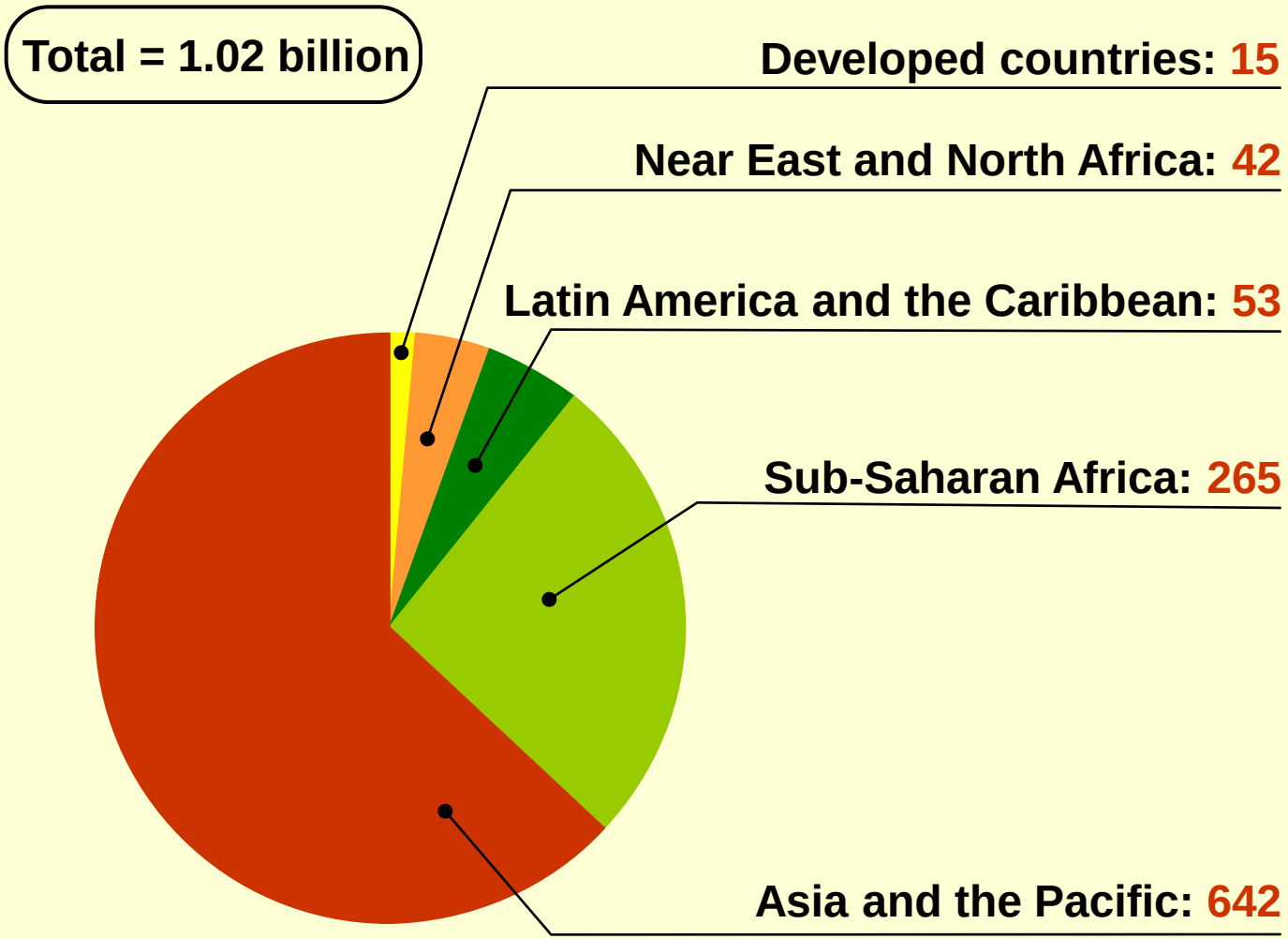
- planting dates
- rice area estimates
- crop status & yield estimates
- crop damage estimates
- crop insurance

Sentinel 1A & B satellites
Global coverage every
6 days 20-m resolution
Free

National/Global Rice Information Gateways



Undernourishment in 2009, by region (millions)



Source: FAO

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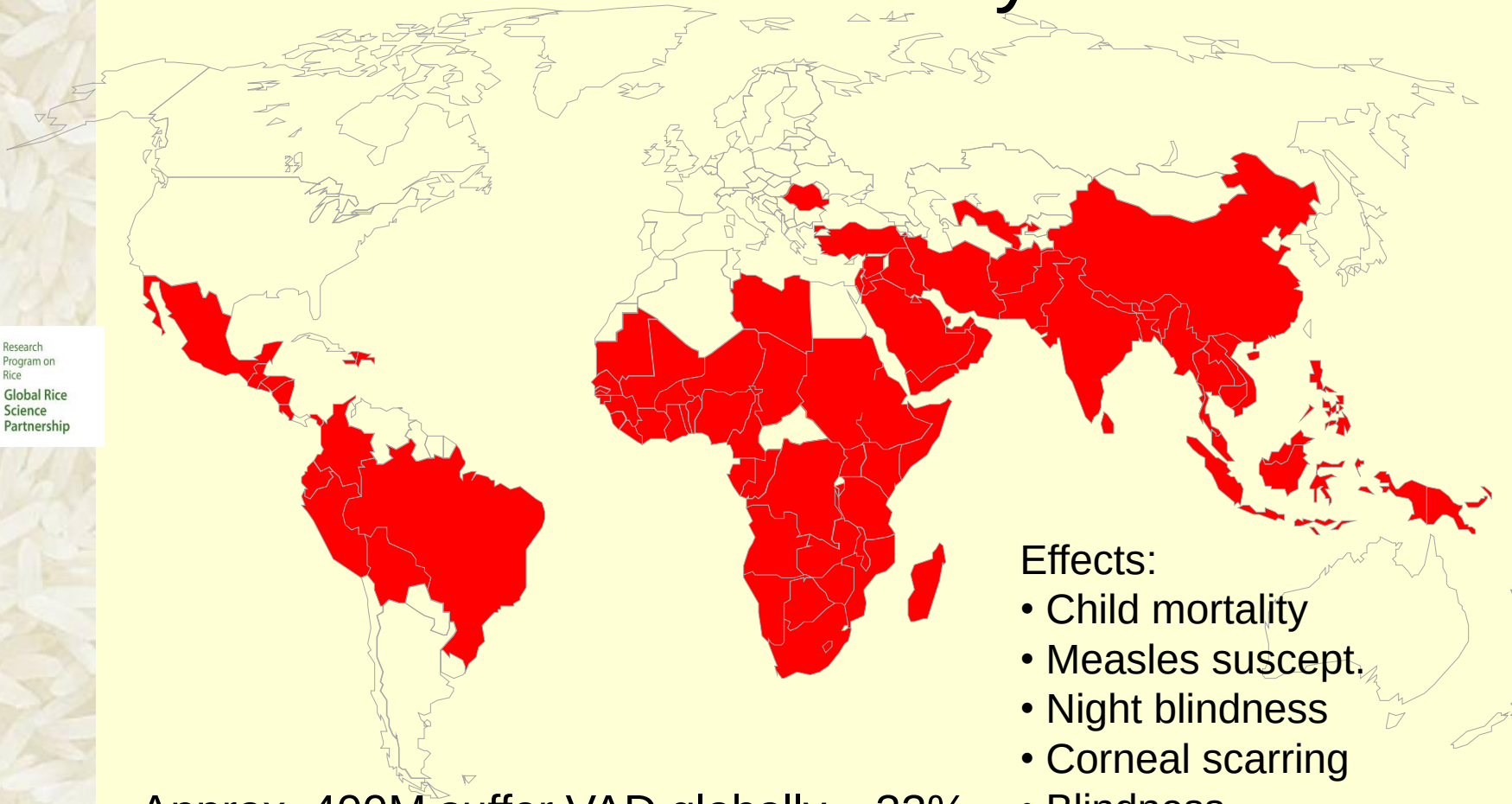
Clinical and Subclinical Vit A Deficiency



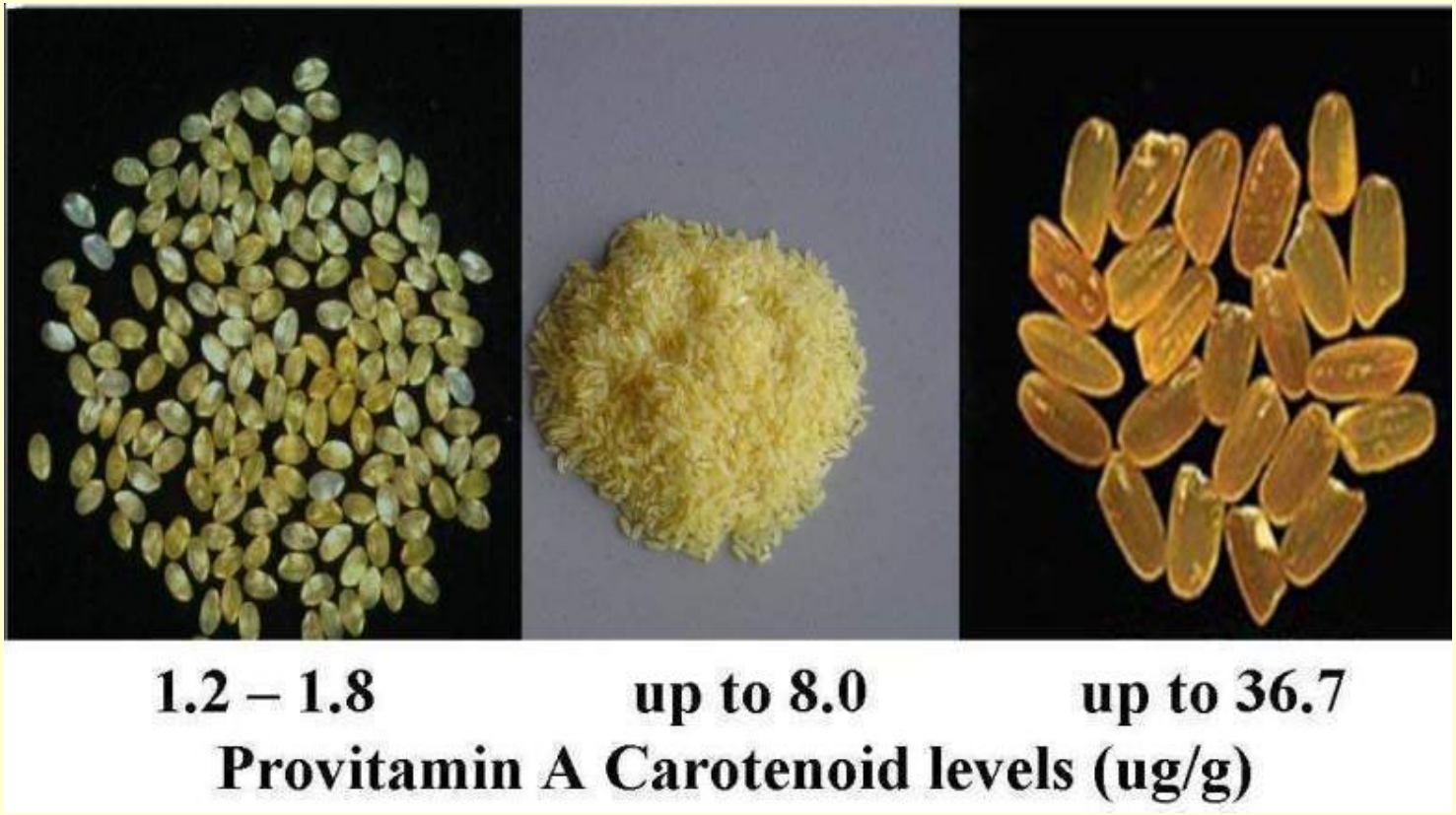
Effects:
- Child mortality
- Measles suscept.
- Night blindness
- Corneal scarring
- Blindness

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

Micronutrient Initiative 2004

IRRI

Combating vitamin A deficiency among the poor: Golden Rice



Work on Golden Rice began in late 1980s…
to consumers in 2014

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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 Rice

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

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Long Term Rice Supplies?

Can we boost yields dramatically?

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Taking some tricks from other grasses

Increase yields by 50%, N – use and water- use efficiency

Recipe for Success in Rainfed Systems?

Greater water use efficiency, greater N-use efficiency, higher yield in maize due to C4

No other evolutionary mechanism exists that could be added to C3 rice to deliver such superior combination of benefits

Maize (C4)

Rice (C3) → (C4)

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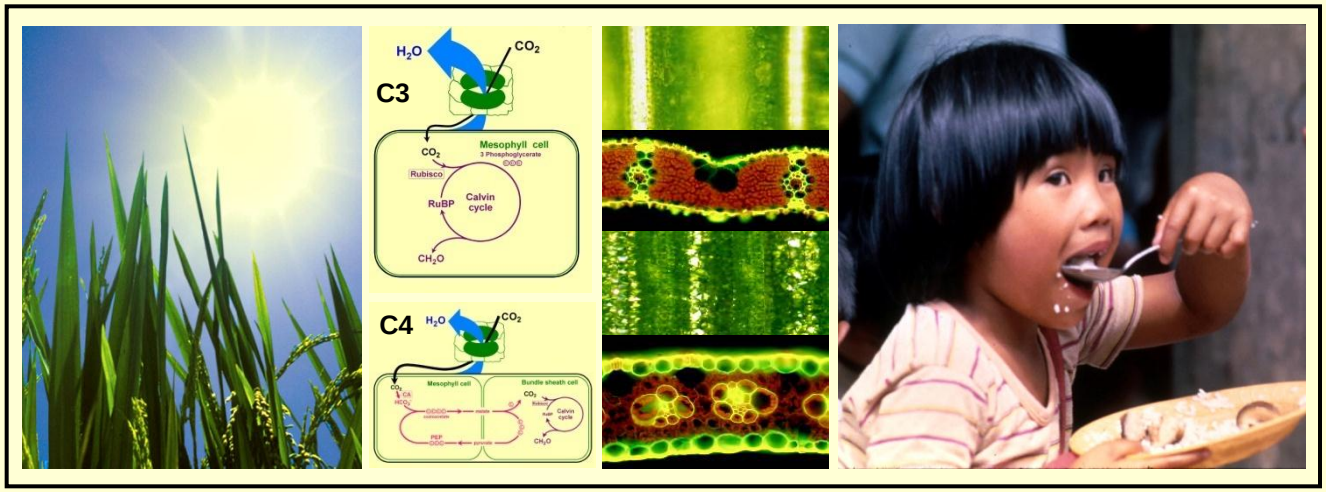
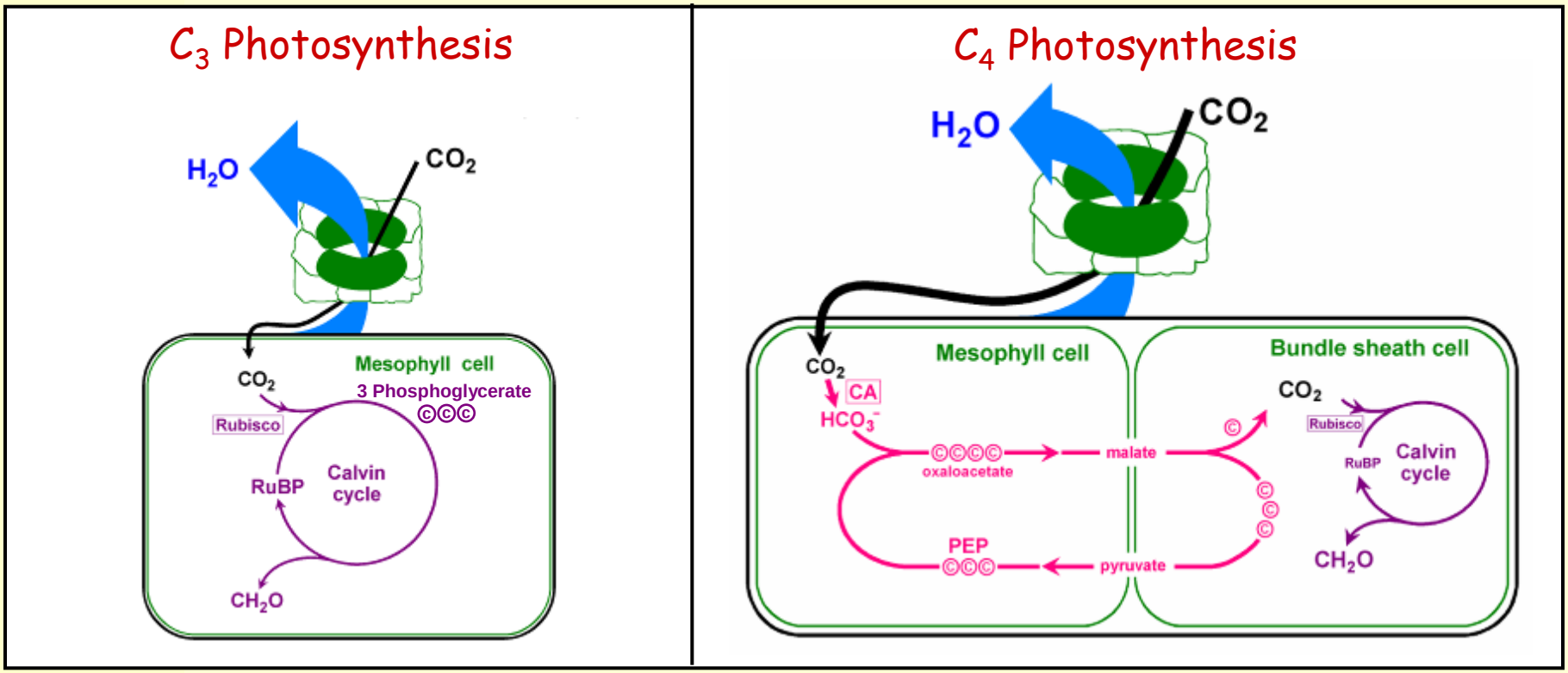
Engineering a C4 rice



IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE

BILL & MELINDA GATES foundation

Transforming Photosynthesis in Rice:
Compressing a Million Years of Evolution to Twenty

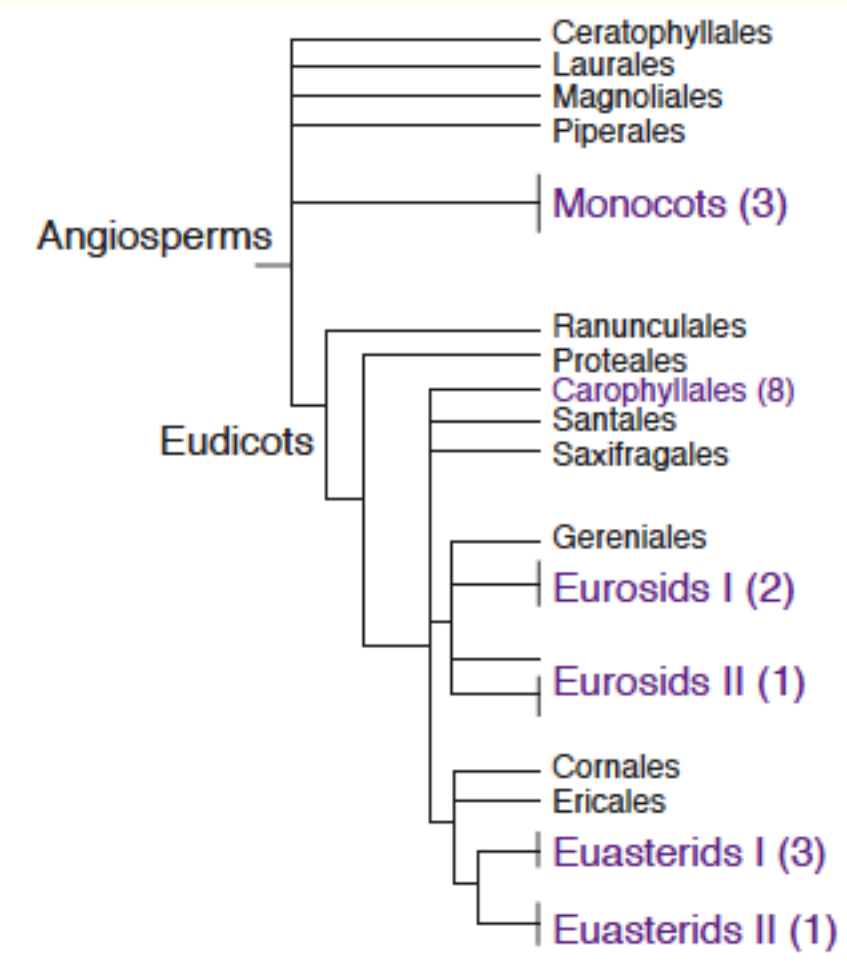


C4 Enhances Photosynthesis Using A Two Compartment CO_2 Concentrating Mechanism

Despite its complexity, C_4 has evolved independently ~62 times about 25-35 mya

C_4 monocots and dicots that are differentiated by ~180 million years share similar mechanisms underlying C_4

Known genes required for C_4 are all found in C_3 plants



With 62 independent lineages, C4 photosynthesis has to be considered one of the most convergent of the complex evolutionary phenomena on planet Earth

Sage et al. 2011

So, it can't be that difficult!? We just want to do in 20 years what takes nature a million…

Simple High Throughput Screens

Capacity
72,000 plants
Screen
24,000 / week

- Growth in low CO_2
- Carbon 12/13 isotope ratio
- High throughput imaging

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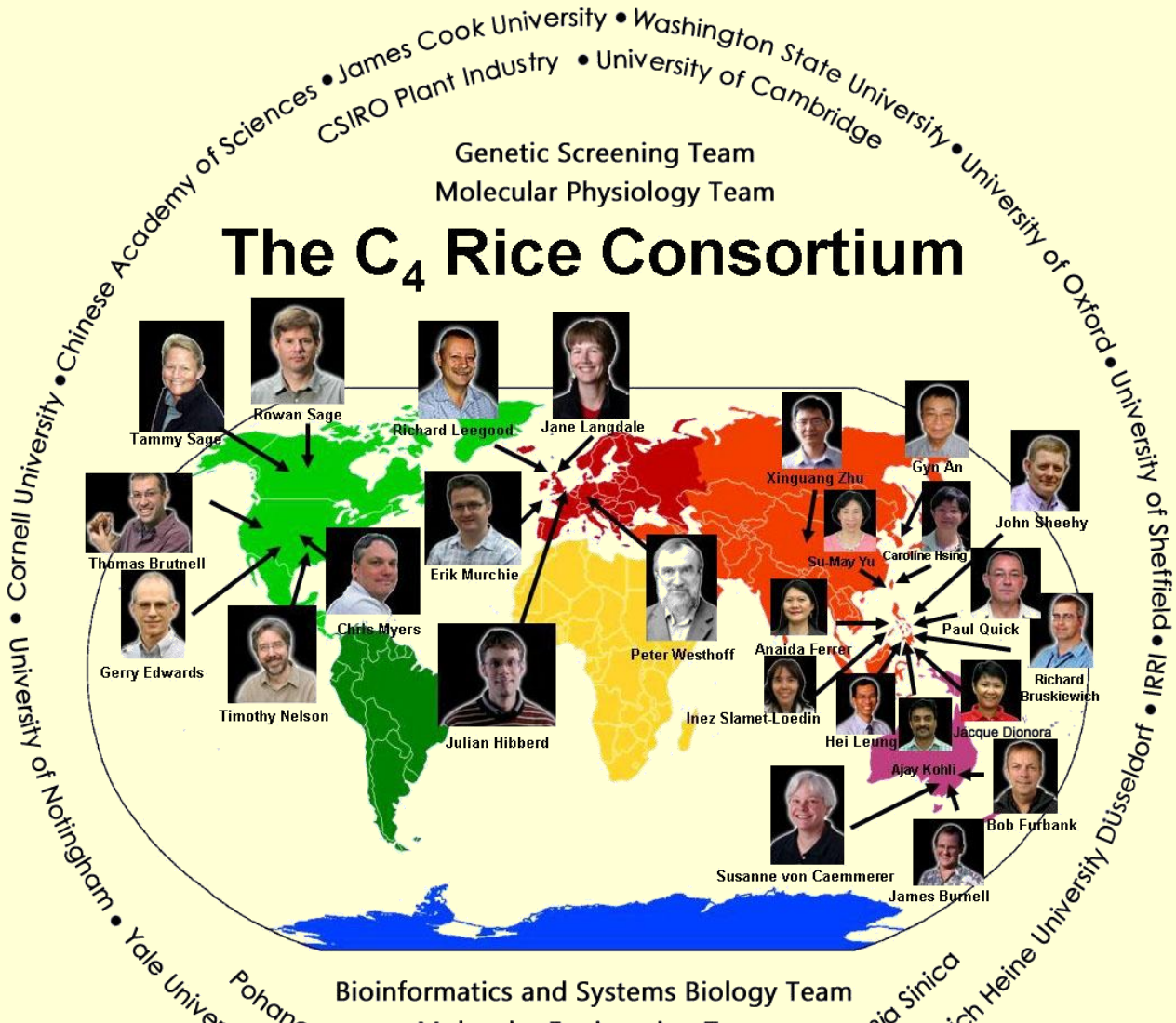

In Summary…

- We need productivity growth but that requires research, development, dissemination
- Global food security depends on sustaining rice systems in the face of climate change
- History shows that science can make a major contribution
- Commitments to the next generation of scientists
- The requirements for success are in place
- The global scientific community is now mobilized
- Powerful link between science and need

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Excite the minds of young scientists

Rice Research to Production course

Rice Science for a Better World

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Thank you

"Since the way to feed the world is not to bring more land under cultivation, but to increase yields, science is crucial."

The Economist

"The Silent Tsunami"

19 April 2008

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Reviving African fields by engaging women farmers (CARE, World Vision)

African rice yields are far below world averages - introduction of basic crop management practices with improved varieties that reflect women Farmer needs and realities can make enormous differences.

Creating a small seed commercial sector in Burundi can help solve two big problems…

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