Methane emissions from rice cultivation: IRRI's mitigation options

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Outline of Presentation

- Significance of CH_4 emissions on Climate Change
- CH_4 emissions from rice cultivation
- Mitigation strategies

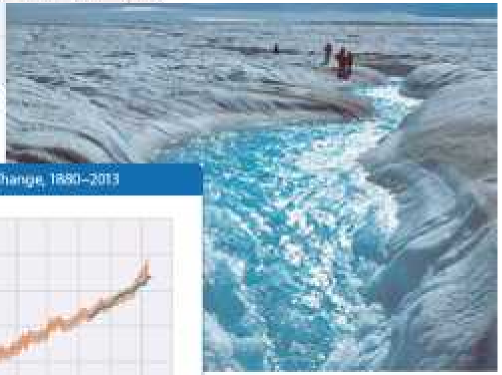
There are many uncertainties about the future climate,
BUT
two universal trends are predicted by most climate change models:

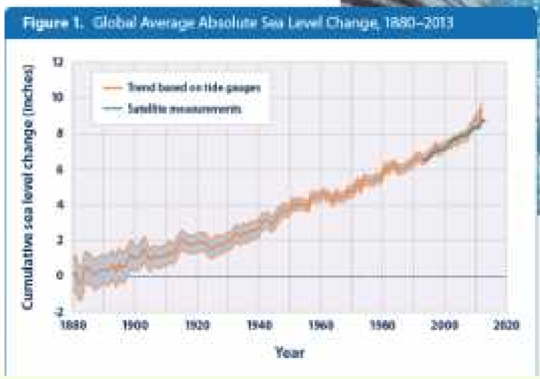
(1) Temperatures will increase

- more heat stress
- Sea level rise (thermal expansion of water and melting of ice)

(2) More frequent and severe climate extremes

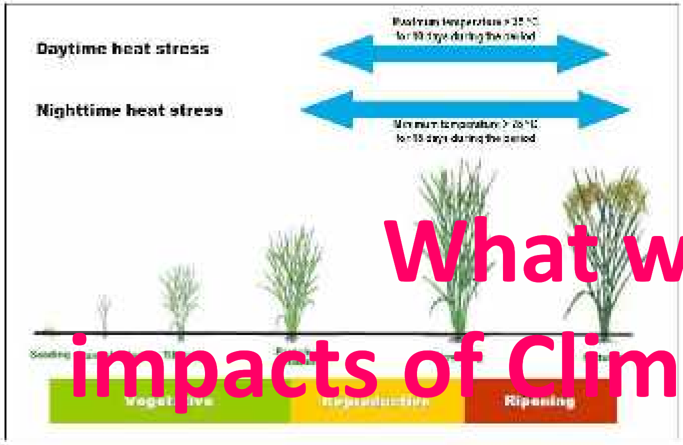
- more floods
- more droughts





Climate Change will Aggravate the Abiotic Stresses in Rice!

(1) Heat stress



What would be the impacts of Climate Change on rice?

daytime

nighttime

Hotspots of heat stress on rice and frequency of occurrence (1983 – 2011)

- extreme heat episodes can irreversibly damage rice yield, grain quality, germination and fertilization
- heat stress during flowering – complete sterility
- heat stress during ripening – reduced grain filling & poor milling quality (more broken grains)

- Due to climate change, the number of hot days and warm nights have increased
- higher nighttime temp – reduced yields by as much as 10% for every 1°C increase in minimum temp due to increase in respiration (Peng et al., 2004)

Climate Change will Aggravate the Abiotic Stresses in Rice!

(2) Drought or water stress

- most widespread and damaging of all abiotic stresses
- major source of yield & economic loss in rice production
- affects all stages of rice growth and development
- the strong effects of drought on grain yield are largely due to the reduction of spikelet fertility and panicle exsertion

- With the onset of climate change, the intensity and frequency of droughts are predicted to increase in rainfed rice-growing areas and droughts could extend further into water-short irrigated areas

Climate Change will Aggravate the Abiotic Stresses in Rice!

(3) Salinity

- NaCl – major salt that causes this problem
- rice is highly sensitive to salt stress in its early growth stage and a few days before panicle initiation to flowering stage
- ECe 3 dS/m – salinity threshold for rice

- When sea level rises due to climate change, saline water will be brought inland and expose more rice growing areas in the low-lying deltas and coastal areas to salty conditions

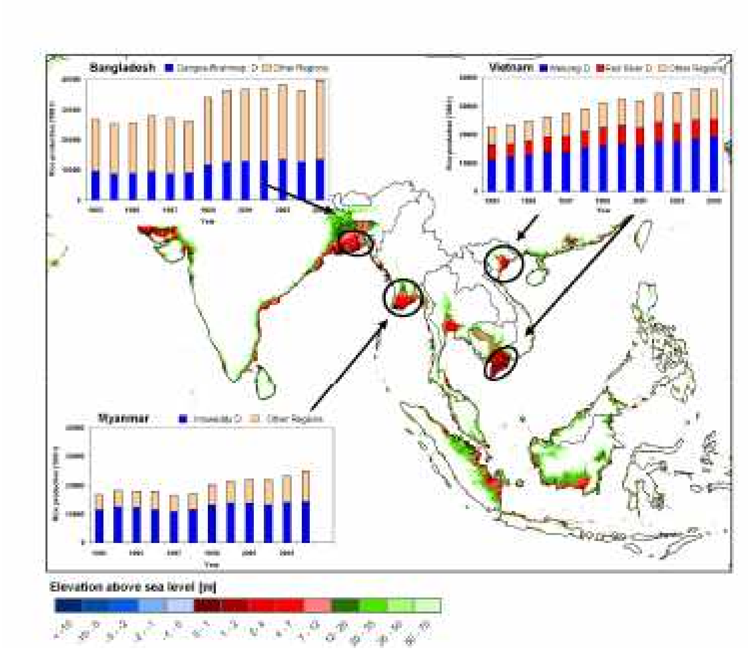
Climate Change will Aggravate the Abiotic Stresses in Rice!

(4) Submergence/ Flooding

➢ Submergence either short-term (flash floods) or long-term (stagnant flooding) can affect rice crops at any stage of growth

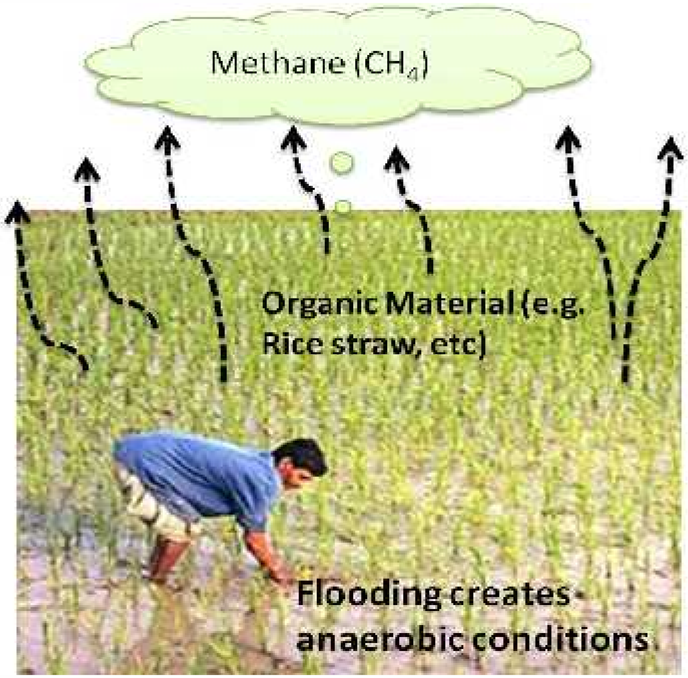
➢ The chances of survival are extremely low when completely submerged during the crop's vegetative stage

Mega deltas in Asia are most vulnerable



➢ With climate change, major flooding events are likely to increase in frequency caused by sea level rise in coastal areas and the predicted increased intensity of tropical storms

Contribution of rice production to greenhouse gas effect



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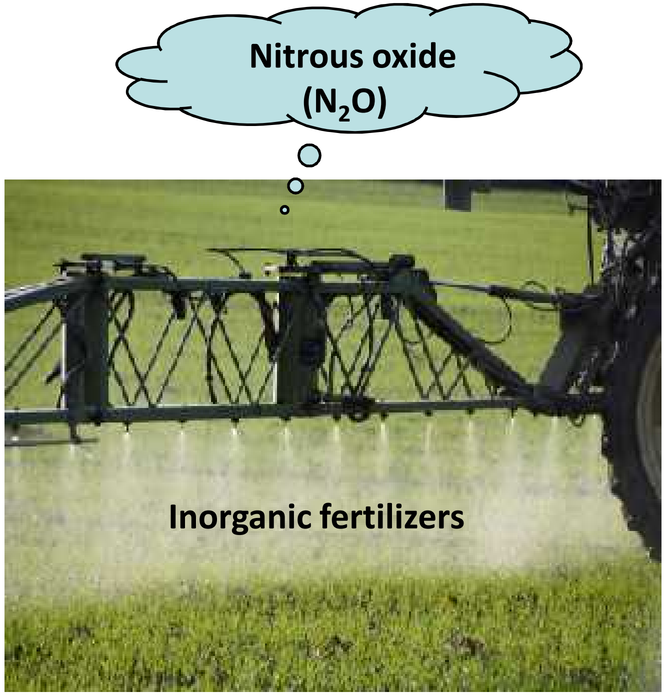


300X

Why is methane important?

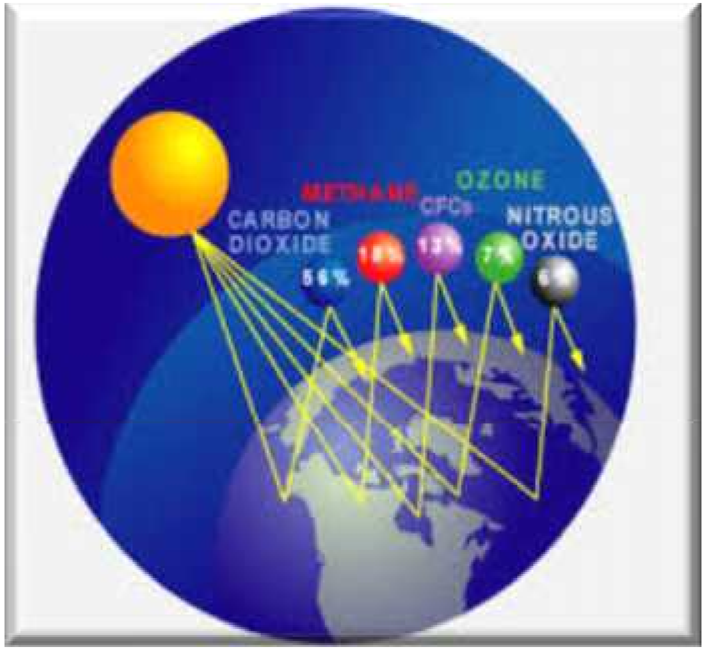
- **radiative forcing: CO_2 (~60%), CH_4 (~20%)**
(Forster et al., 2007)

- **CH_4 GWP: 25 (100-yr time horizon)**
(Forster et al., 2007)

- **CH_4 concentration: 0.7 to 1.80 ppm V**
(Hartmann et al., 2013)

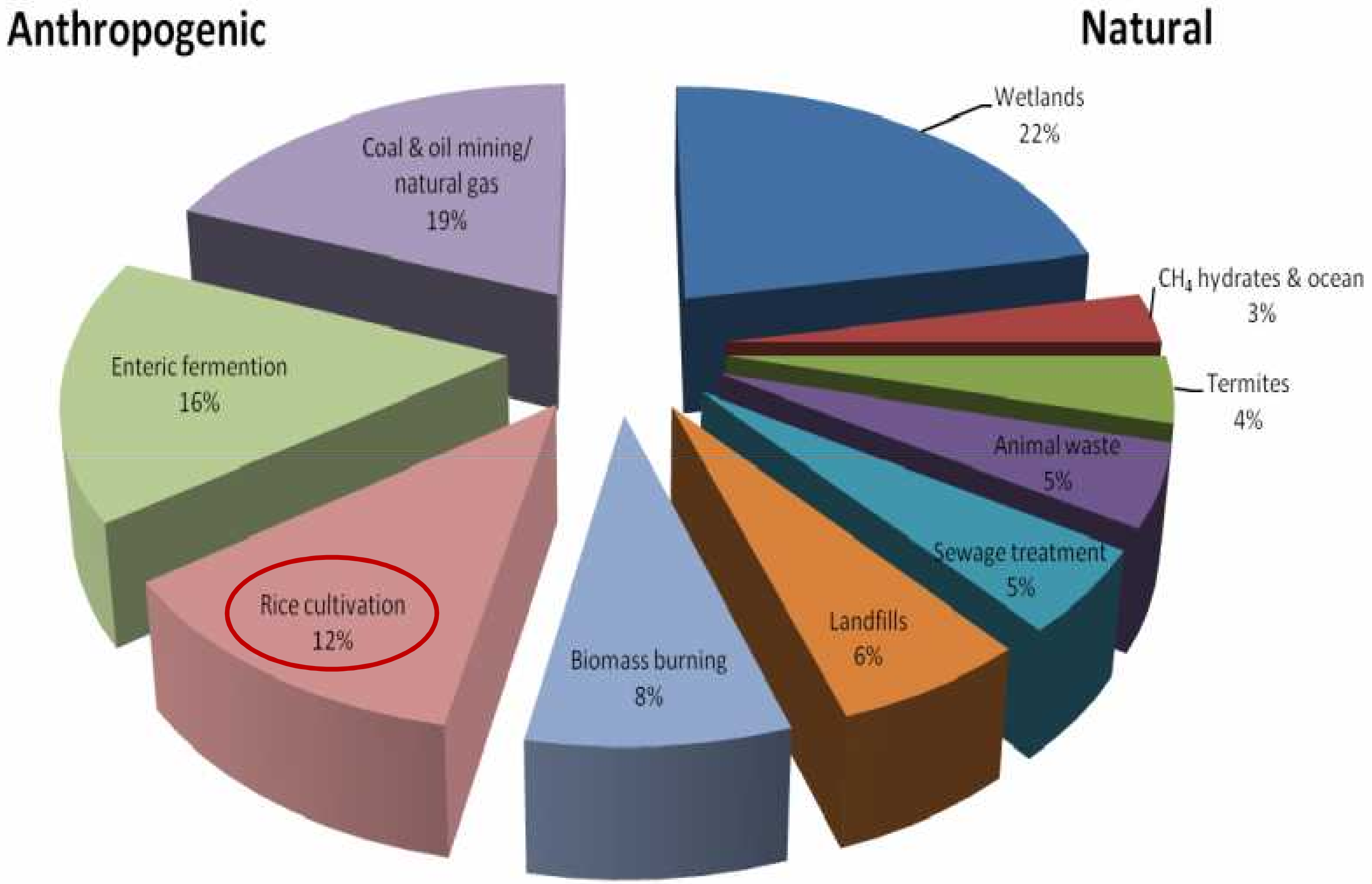
- **total global CH_4 budget: 500-600 Tg CH_4 yr^{-1}**
(Dlugokencky et al., 2011)

- **Residence time: CH_4 (~9 yrs), CO_2 (~100 yrs), N_2O (~170 yrs)**



- Because CH_4 is both a powerful GHG and short-lived compared to CO_2, achieving significant reductions would have a rapid and significant effect on atmospheric warming potential.

Methane Sources



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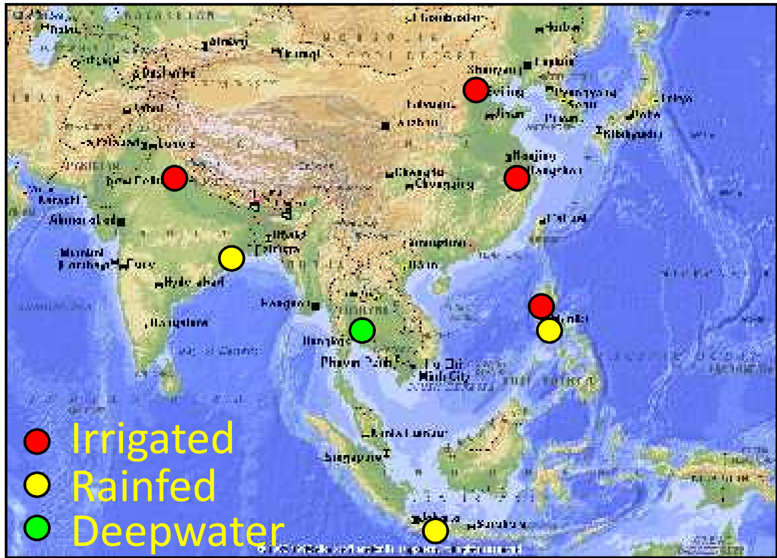
Baseline Methane Research
(funded by US-EPA, 1991-1995)

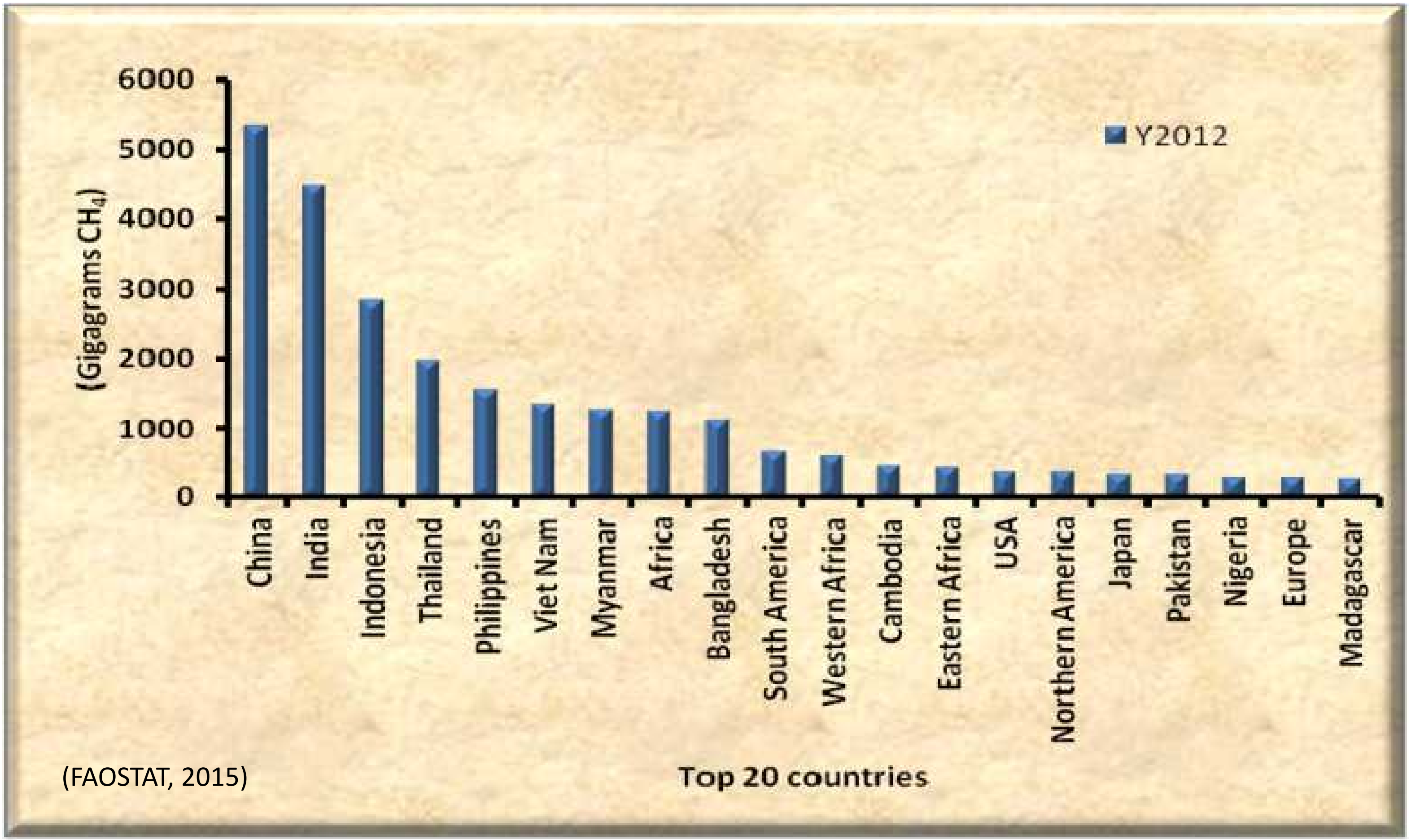


Interregional Program on Methane Emissions from Rice Fields
(funded by UNDP/GEF, 1993-1999)

Rice ecosystems in Asia

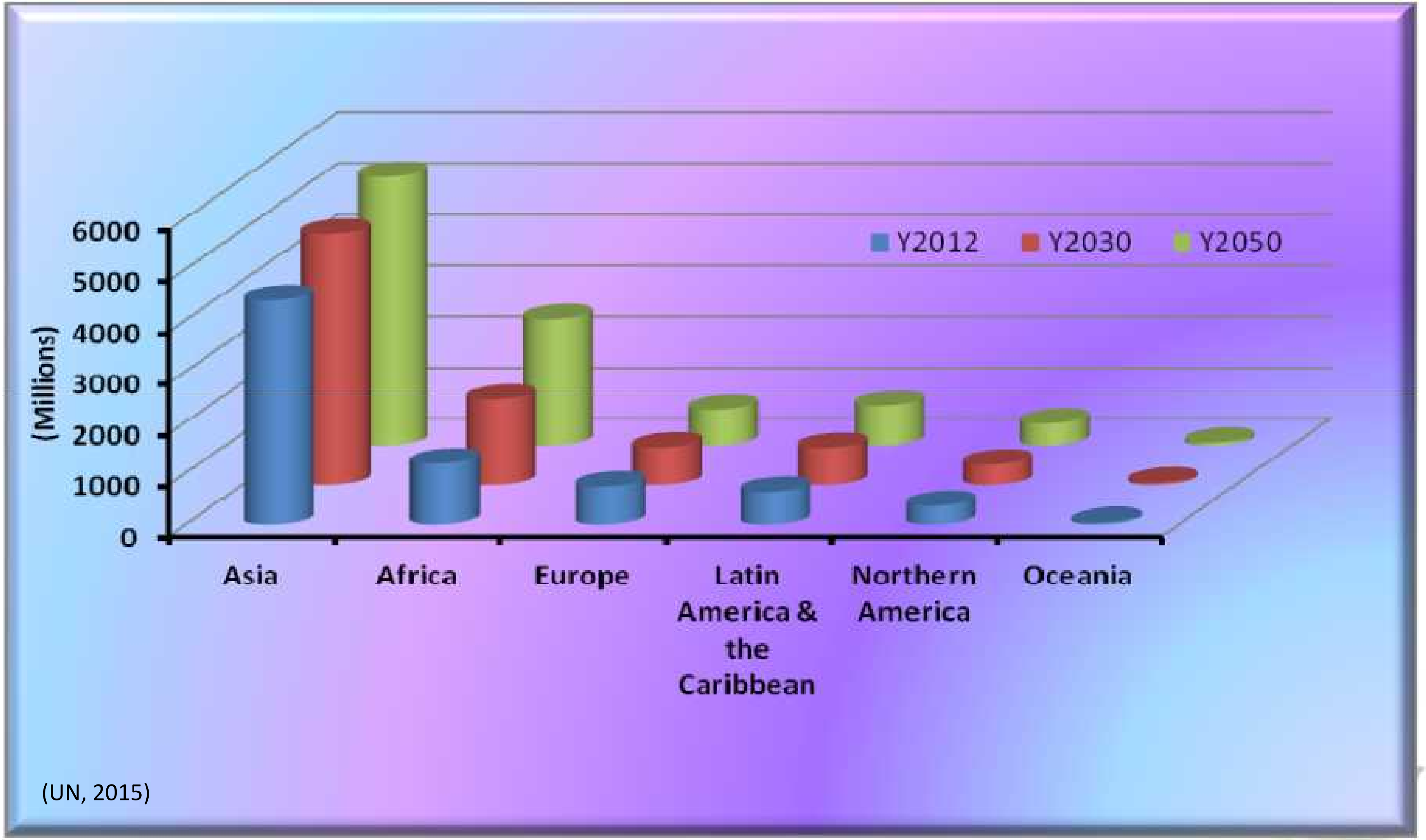
CH_4 emissions from different rice fields:
irrigated rice ≥ continuously flooded rice > flood prone rainfed rice ≥ deepwater rice > drought prone rainfed rice > tidal rice

Methane emissions from rice paddy

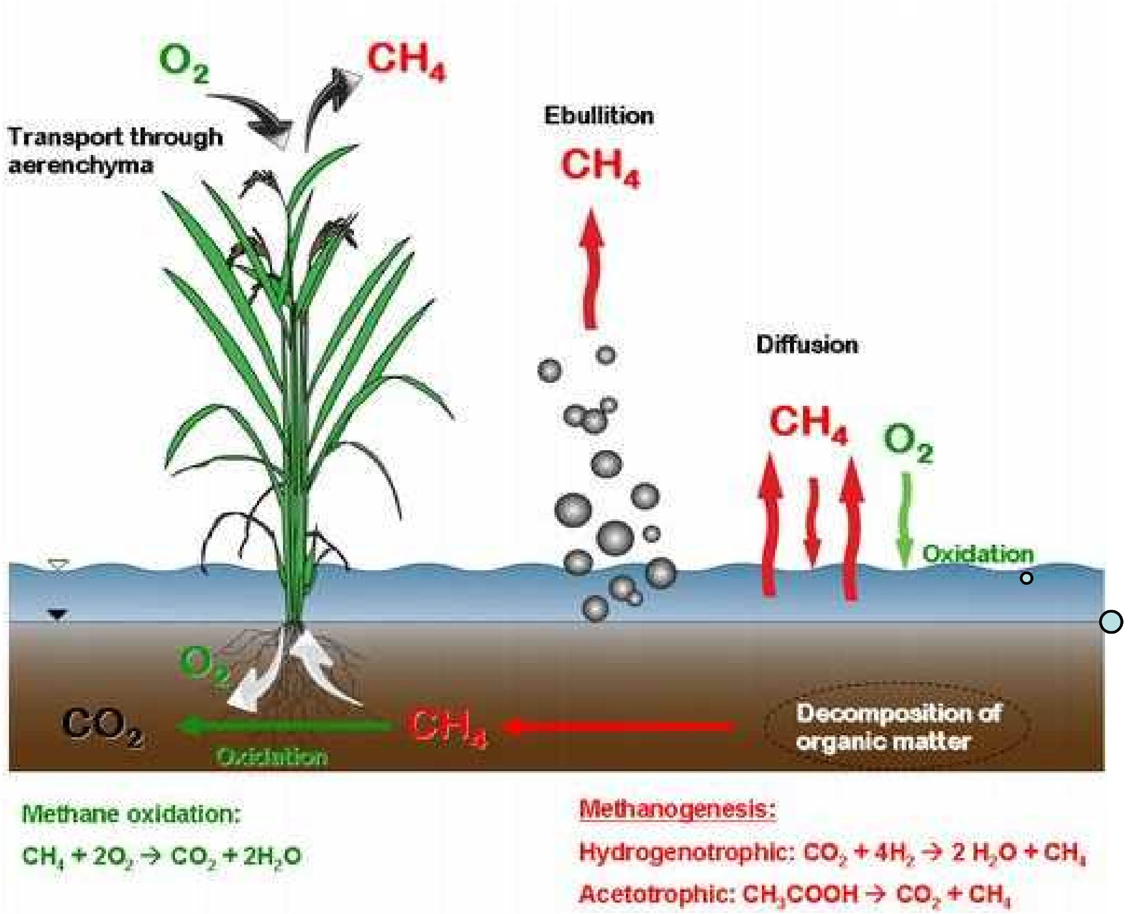


About 75% of our global rice production comes from irrigated rice-based cropping systems

Increasing Human Population



Methane in paddy fields

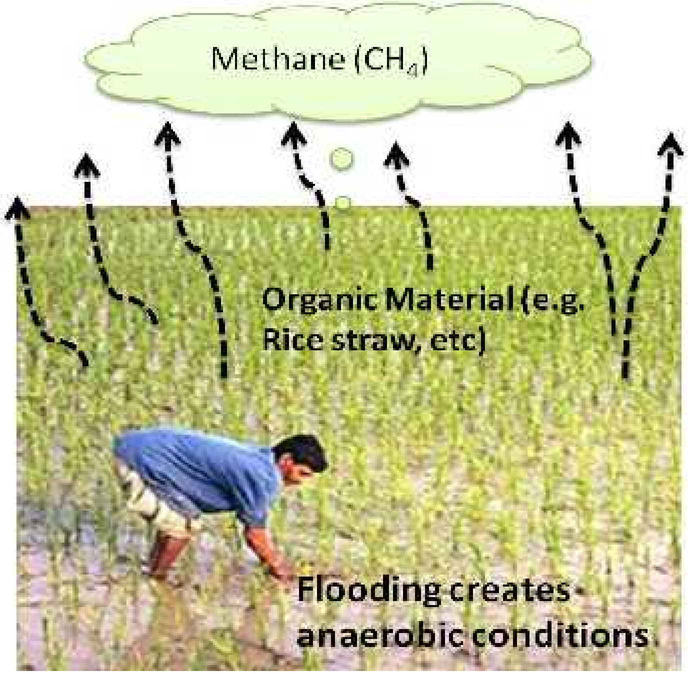


Pools: entrapped CH_4, dissolved CH_4 in soil solution
Fluxes: plant-mediated, ebullition, diffusion

Flooding creates anaerobic condition

Factors affecting CH_4 emissions in paddy fields

- Flooding (Eh < -150 mv)
- Organic substrate (straw residues, green manure, animal manure)
- Soil type (heavy clay soils)
- Soil temperature (35°C)
- Soil pH 6.4 to 7.8
- Tillage
- Rice cultivar
- Fertilizers containing nitrates and sulfates inhibit CH_4 production



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Mitigation options

- water-saving practices
  - mid-season drainage
  - intermittent irrigation
  - safe alternate wetting and drying (AWD)
- efficient nutrient management
- smart management of rice residues

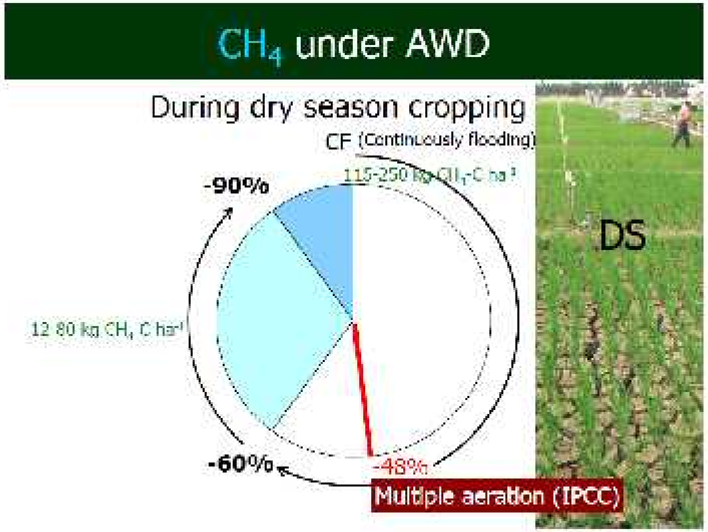
Safe alternate wetting and drying (AWD)

- Start AWD at 10 DAT with 5-cm floodwater
- Irrigate when water is 15-cm below soil surface
- Keep 5-cm floodwater at flowering (one week before and one week after)

- Save water: 15-30% less irrigation water
- Maintain yield: No yield penalty
- Increase water productivity
- Increase profit in deep well and shallow tube well systems

- Message for farmers: 'Water is there even when you can't see it'

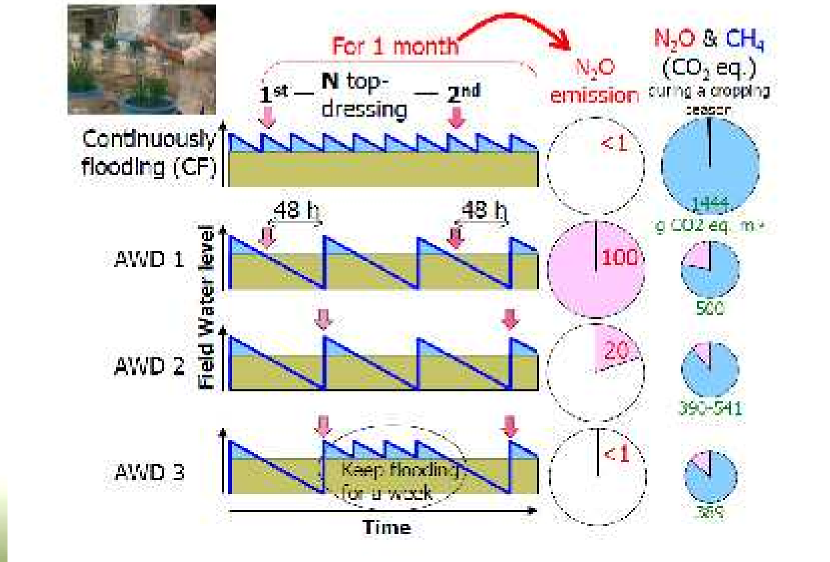
AWD reduces GWP contribution of N_2O and CH_4



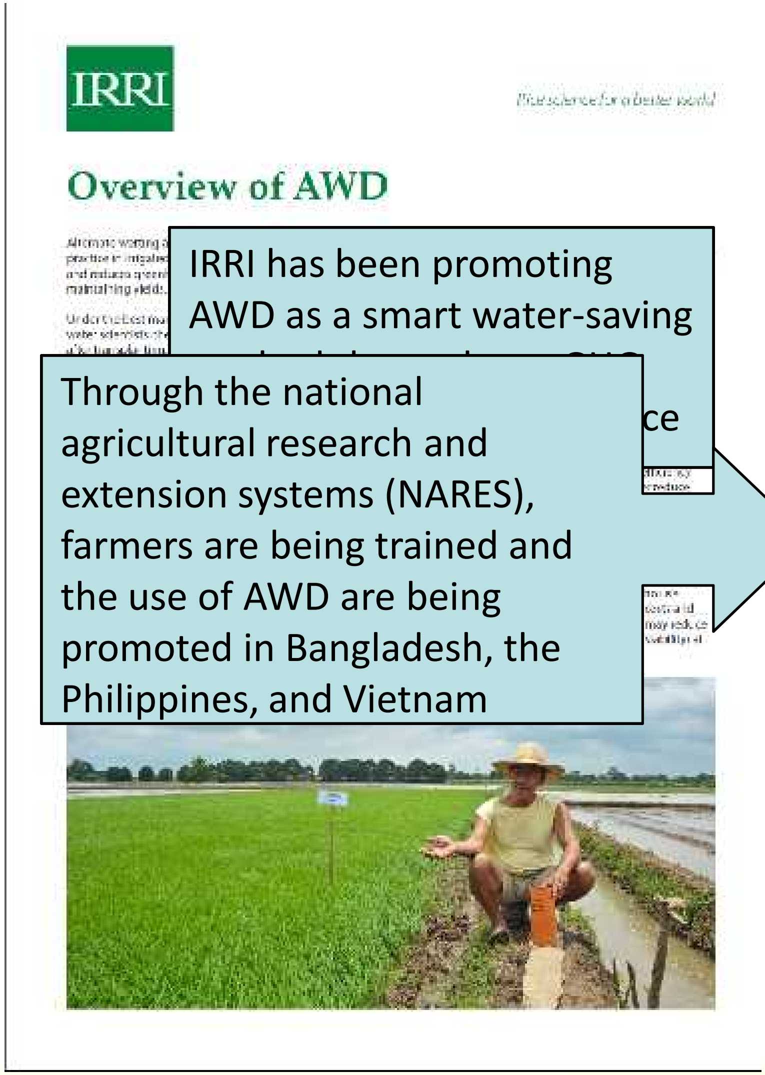
- AWD decreased CH_4 emissions by 60–90% during the DS compared with continuous flooding (CF) (Hosen et al., 2010)

- N topdressing immediately before or after irrigation (AWD 2) decreased N_2O emissions by 80% compared with N topdressing 2 days before irrigation (AWD 1)

- When the field was kept flooded for a week after N topdressing (AWD 3), N_2O emission decreased similar to CF



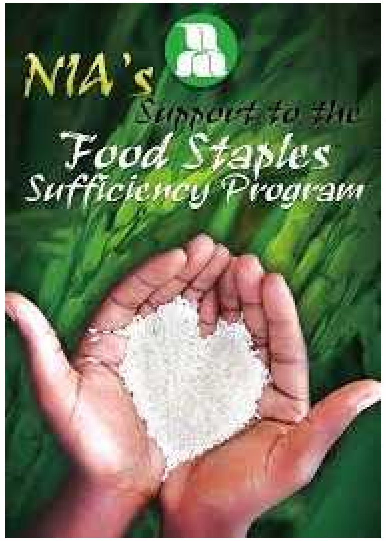
Promoting AWD



IRRI has been promoting AWD as a smart water-saving
ce

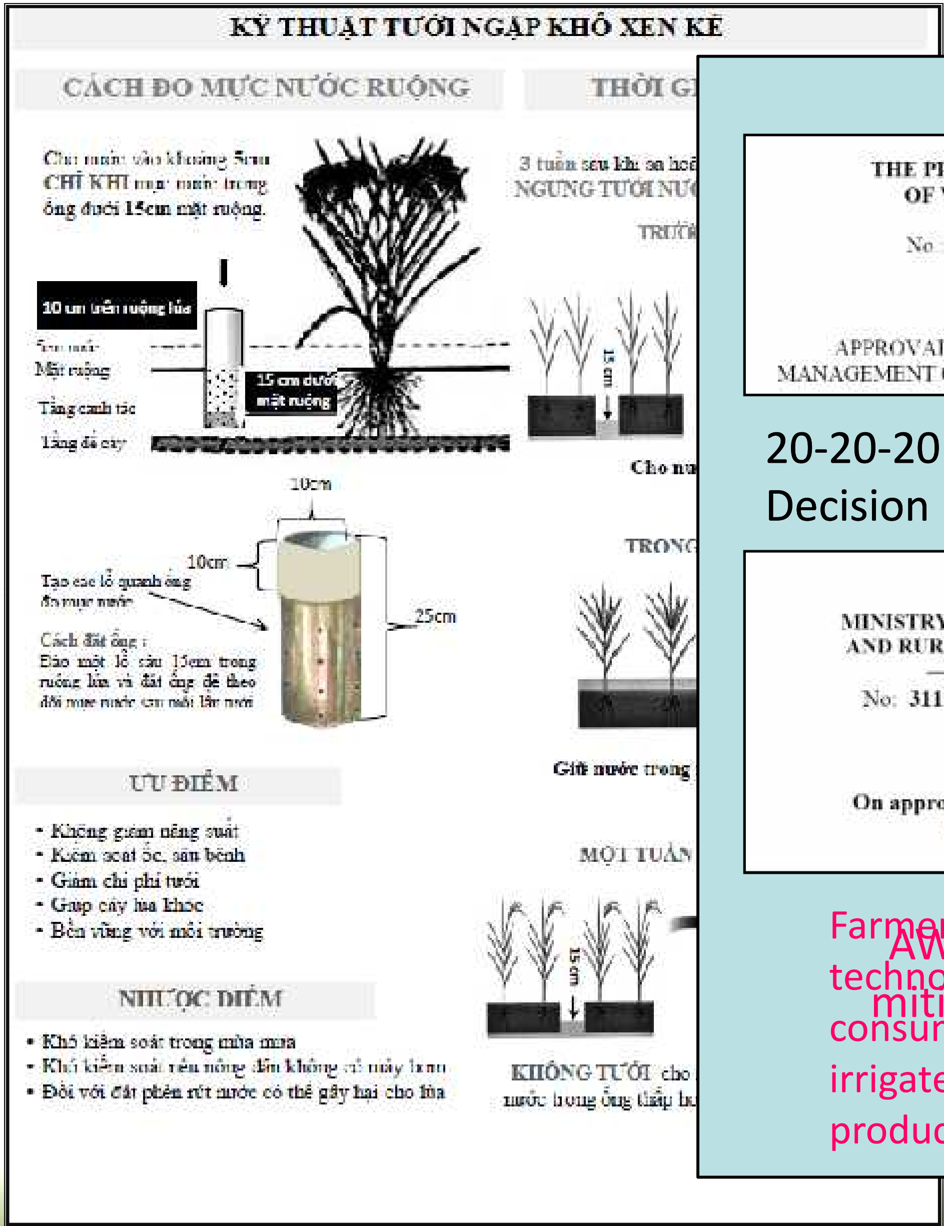
Through the national agricultural research and extension systems (NARES), farmers are being trained and the use of AWD are being promoted in Bangladesh, the Philippines, and Vietnam

AWD is part of the Palay Check System (Philippines)



PALAYCHECK SYSTEM

AWD Propagation in Vietnam



THE PRIME MINISTER
OF VIETNAM SR
No.: 1775/QD-TTg

SOCIALIST REPUBLIC OF VIET NAM
Independence - Freedom – Happiness
Ha Noi, November 21, 2012

DECISION

APPROVAL OF PROJECT OF GREENHOUSE GAS EMISSION MANAGEMENT; MANAGEMENT OF CARBON CREDIT BUSINESS ACTIVITIES TO THE WORLD MARKET

20-20-20
Decision

MINISTRY OF AGRICULTURE
AND RURAL DEVELOPMENT
No: 3119 /QD-BNN-KHCN

SOCIALIST REPUBLIC OF VIETNAM
Independence- Freedom-Happiness
Hanoi, date on 16 Dec. 2011

DECISION

On approving programme of Green House Gas (GHG) emissions reduction in the Agriculture and Rural Development sector up to 2020

Farmers should use/apply AWD irrigation technology to not only greatly save water consumption and reduce GHGs emissions in irrigated rice fields, but also increase rice productivity.

AWD is directly mentioned as one mitigation option by the Ministry of Agriculture of Vietnam

CCAC Paddy Rice Component:

Implementing Partners: IRRI in Asia and CIAT in Latin America
(with support from CCAFS)

First-Mover Countries (Partner Countries for Implementation):

Viet Nam Bangladesh Colombia

Goal: To disseminate alternate wetting and drying (AWD) on large scale to facilitate both, more stable food supply and reduction in methane emissions.

Efficient Nutrient Management

- Rice Crop Manager is a computer and mobile phone-based application
- provides farmers with site- and season-specific recommendations for fertilization
- allows farmers to adjust nutrient application to crop needs in a given location and season

Smart management of rice straw residues

Shallow tillage of residues immediately after harvest

Partial aerobic decomposition of residues under dry fallow condition

Impact of straw incorporation & water management during fallow and growing periods on reduction in CH_4 emissions

Reference	Year/Season	Straw Residue	Fallow period	Growing period	CH_4 emission (kg CH_4 ha^{-1})	% CH_4 reduction
Wassmann et al., 1996	1992 WS	incorporated	Flooded	Flooded	193 ± 41	(reference)
	1993 DS					
	1993 WS					
Alberto et al., 2015	2013 WS	incorporated	Dry	Flooded	106 ± 20	45
	2014 DS					
	2014 WS					
Alberto et al., 2015	2013 DS	incorporated	Dry	Intermittent	53 ± 14	73
	2015 DS			AWD		

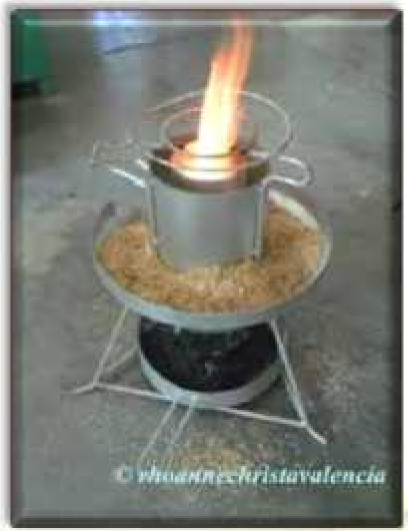
Smart management of rice straw residues

Shallow tillage of residues immediately after harvest

Partial aerobic decomposition of residues under dry fallow condition

Use biochar instead of fresh rice straw

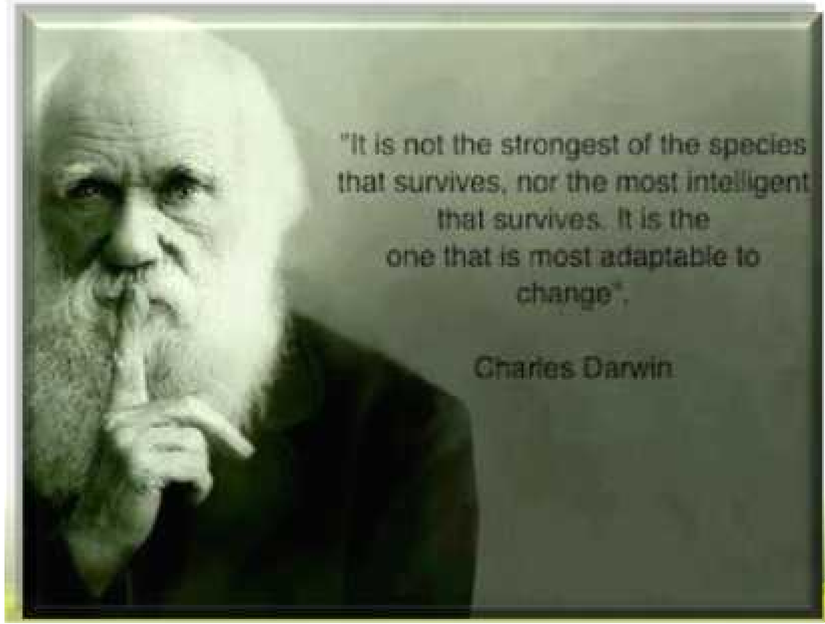
Innovative handling and uses of rice straw and rice husks



Key Messages

(Richards and Sander, 2014)

- Flooded rice produces approximately 20-40 Mt of CH_4 per year, or about 10-12% of the anthropogenic emissions from the agriculture sector globally.
- Alternate wetting and drying (AWD) is a rice management practice that reduces water use by up to 30% and can save farmers money on irrigation and pumping costs.
- AWD reduces methane emissions by 48% without reducing yield.
- Efficient nitrogen use and application of organic inputs to dry soil can further reduce methane emissions


"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change".
Charles Darwin

Two approaches

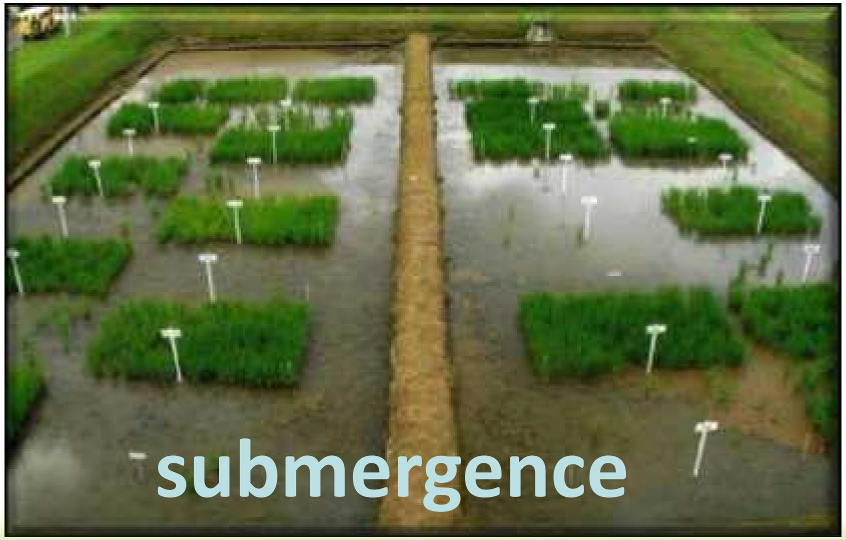
- Mitigation: develop new technologies that can reduce greenhouse gas emissions and increase the C sequestration in biomass and soil (reduce the C footprint)

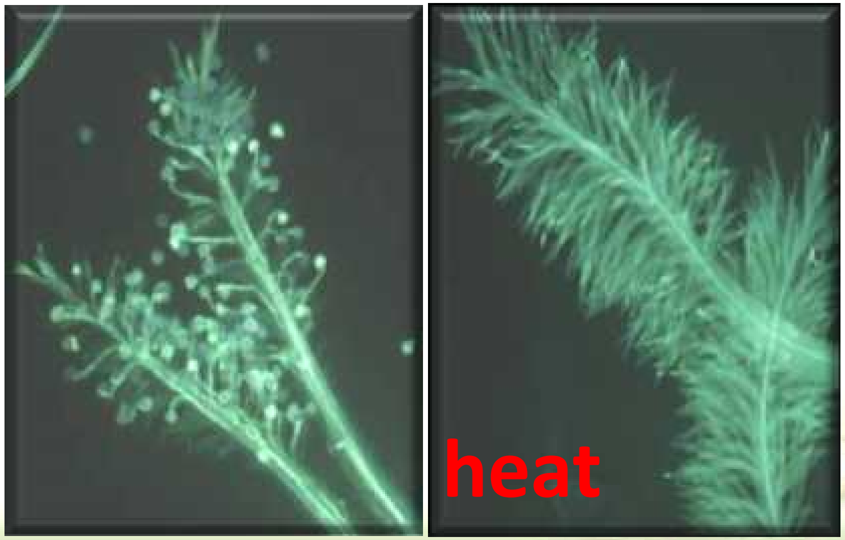
- Adaptation: development of rice plants and crop management to withstand extreme climate and to make rice-cropping systems more resilient

Adaptation strategies

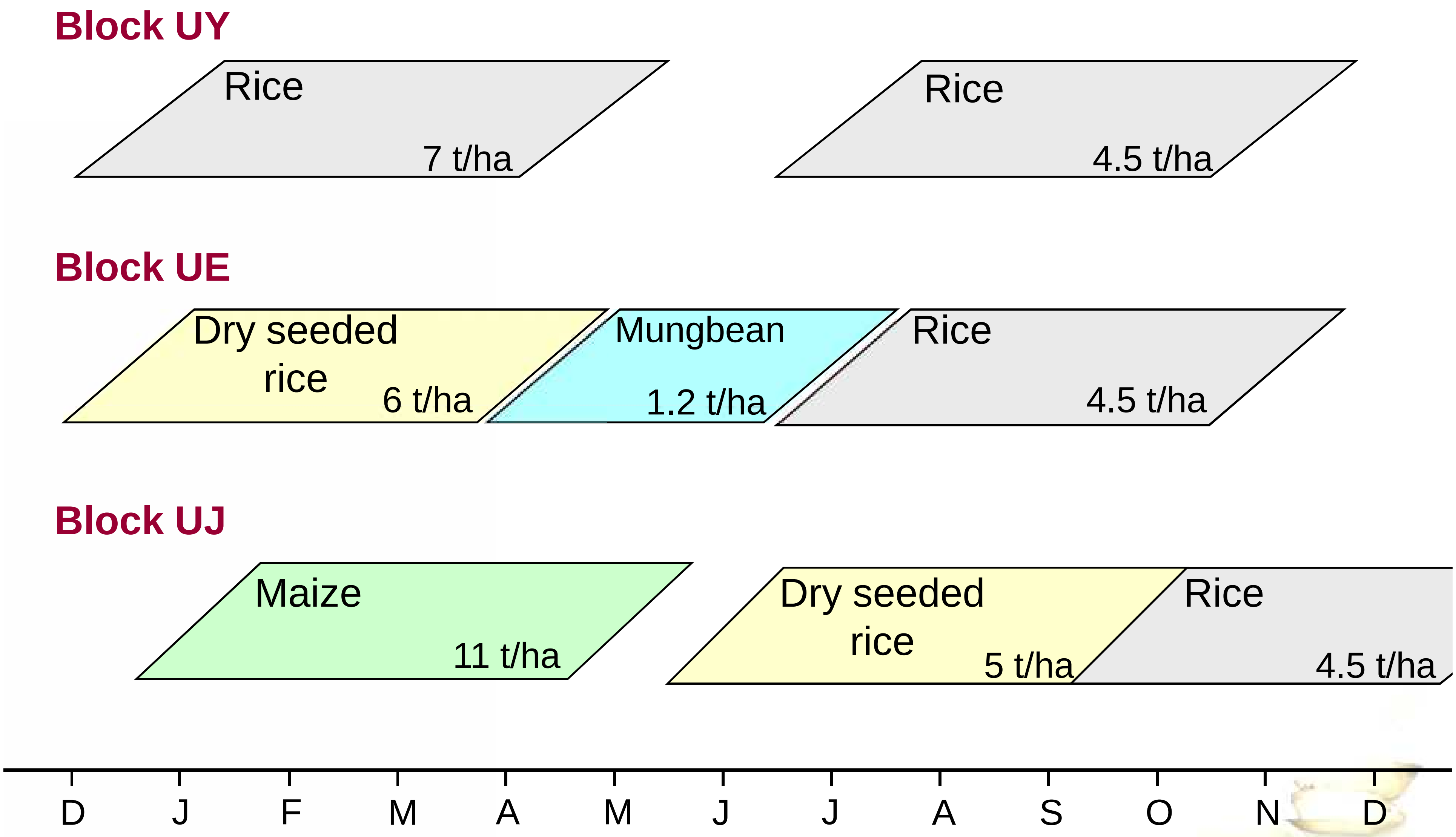
- developing climate-proof rice varieties
- crop diversification
- crop intensification
- decision support systems

Making rice climate-proof





Shifting from traditional rice cultivation to crop diversification and intensification



WeRise (weather-rice-nutrient integrated decision support system)

http://irri.org/tools-and-databases/werise

Weather advisory

Grain yield advisory

- WeRise provides complimentary information to existing systems
- WeRise can describe the characteristics of upcoming rainy season (start/end of season, distribution of rainfall, flood/drought occurrences) and can predict GY of farmers' preferred varieties as a function of sowing date, timing of appropriate fertilizer application at crucial crop growth stages

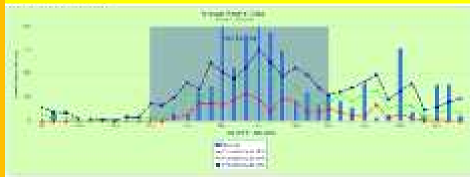
Available information from WeRise

Flood 1 in 5 years

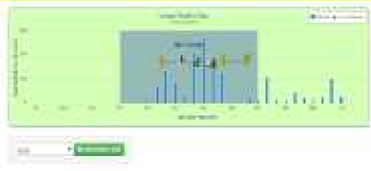
Drought 1 in 5 years

Predicted 10 days rainfall

Weather prediction (10days)



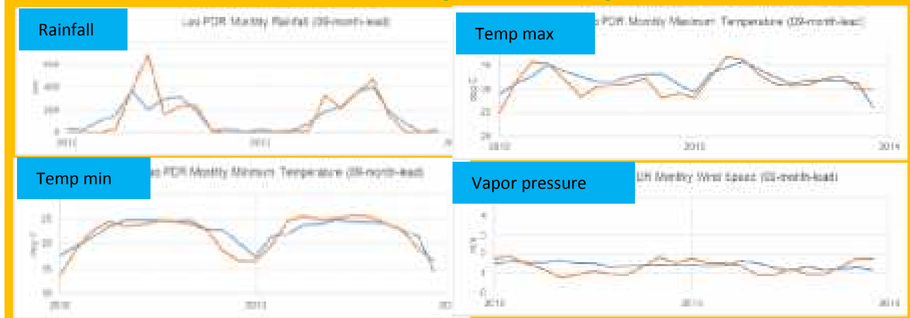
Cropping calendar



GY prediction at different sowing dates

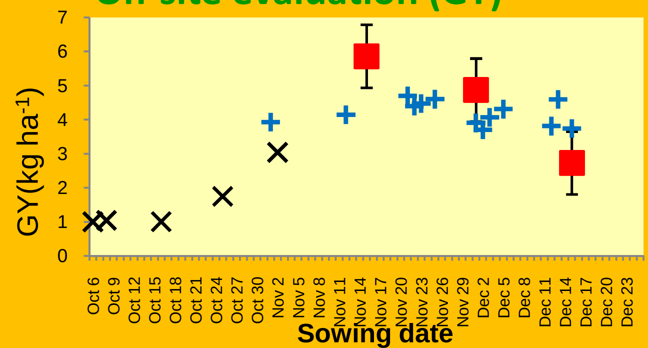
Optimal fertilizer application timings

On-site evaluation (Weather)



Observed WeRise Prediction

On-site evaluation (GY)



■ WeRise prediction

+ WeRise Field testing

× Farmers' practice

Variety: IR64

Location: C Java

Operation of Mobile Phone App

Obtain site-specific information from farmer/ operator

Provide management recommen-dation

Cloud based server

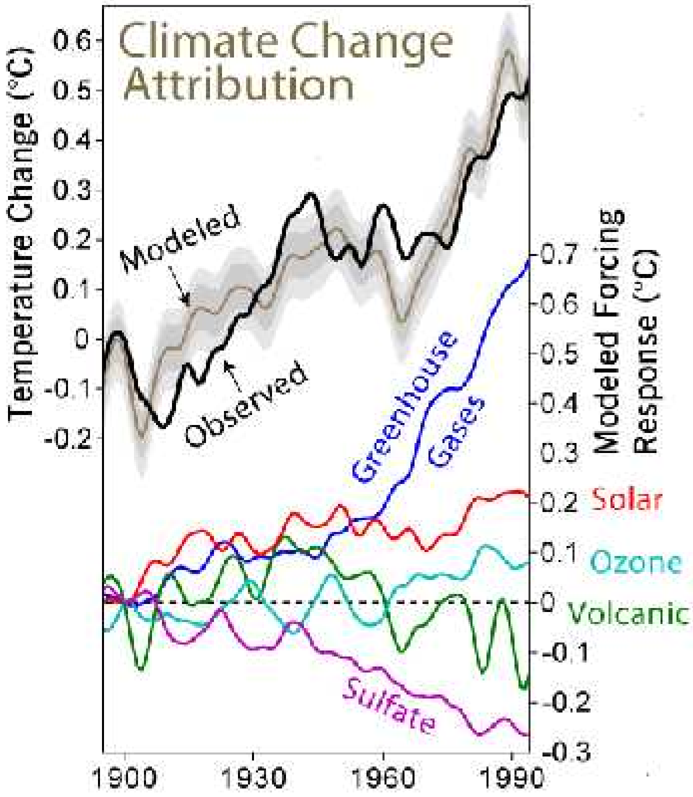
Rice Crop Manager
- Nutrients
- Weeds
- Irrigation
- ….

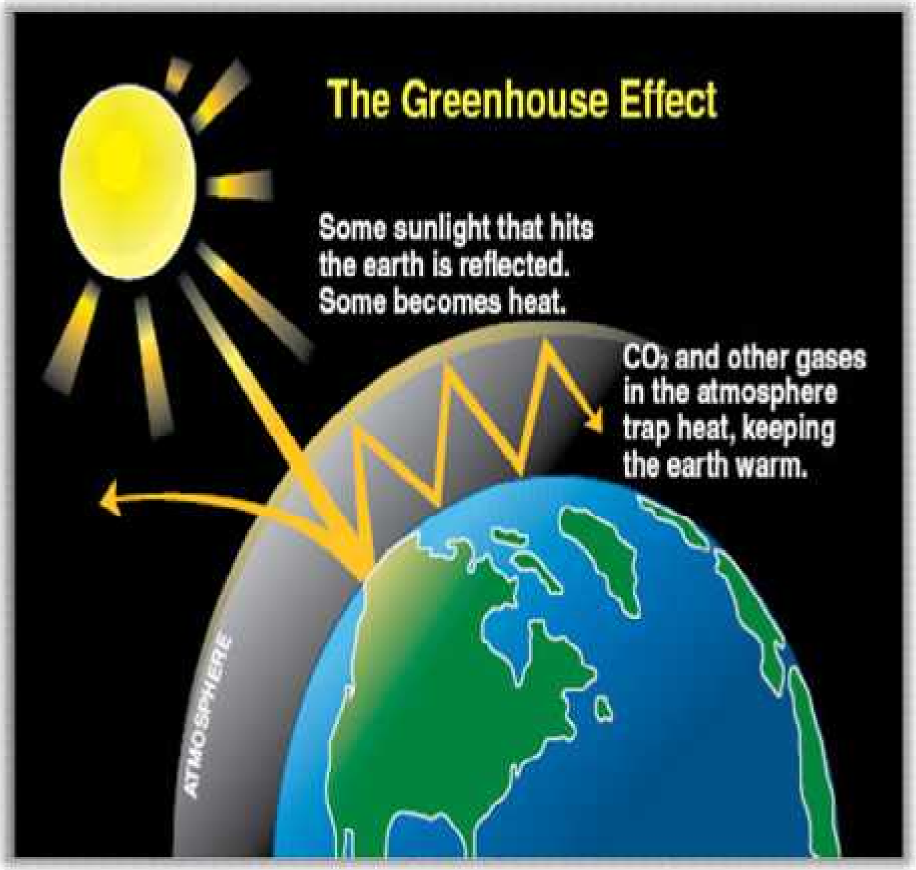
New Modules
- GHG emission calculator
- Climate-adjusted yield targets

Climate-Informed Rice Crop and Low Emission Manager

=> CIRCLE Manager

Thank you


Climate Change
Attribution
Temperature Change (°C)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
Modeled
Observed
Greenhouse
Gases
Modeled Forcing
Response (°C)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
Solar
Ozone
Volcanic
Sulfate
1900
1930
1960
1990


The Greenhouse Effect
Some sunlight that hits
the earth is reflected.
Some becomes heat.
CO_2 and other gases
in the atmosphere
trap heat, keeping
the earth warm.
ATMOSPHERE