How rice can contribute to solving the climate crisis

Bjoern Ole Sander
Senior Scientist
International Rice Research Institute

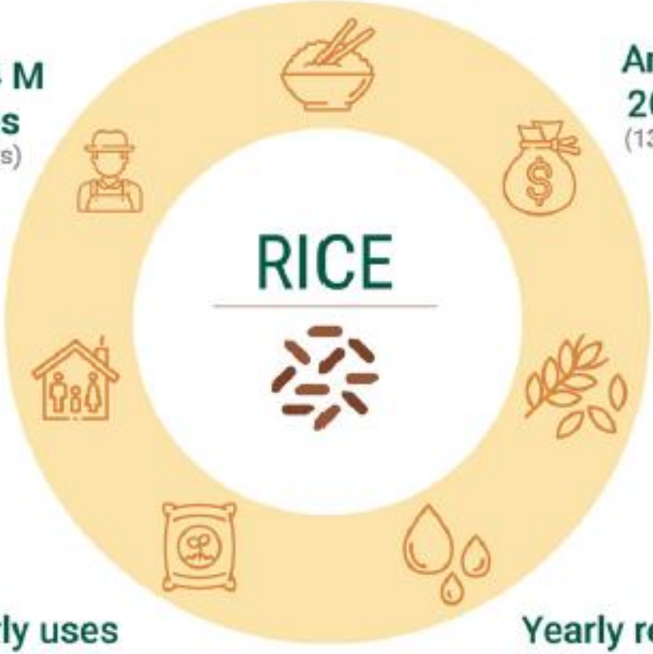
Outline

- Rice – food security- climate change nexus
- A holistic Climate Change Mitigation Strategy:
  - Current Technologies
  - Adoption enablers
  - New frontiers

Feeds 4 billion people
(56% of world population)

Grown by 144 M farm families
(25% world farmers)

Annual value of 206 billion $$$
(13% world crop value)



Home to 400 M rural poor
(40% of world poor)

Harvested from 166 MHa
(10% world crop land)

Yearly uses 25 MT fertilizers
(15% of world total)

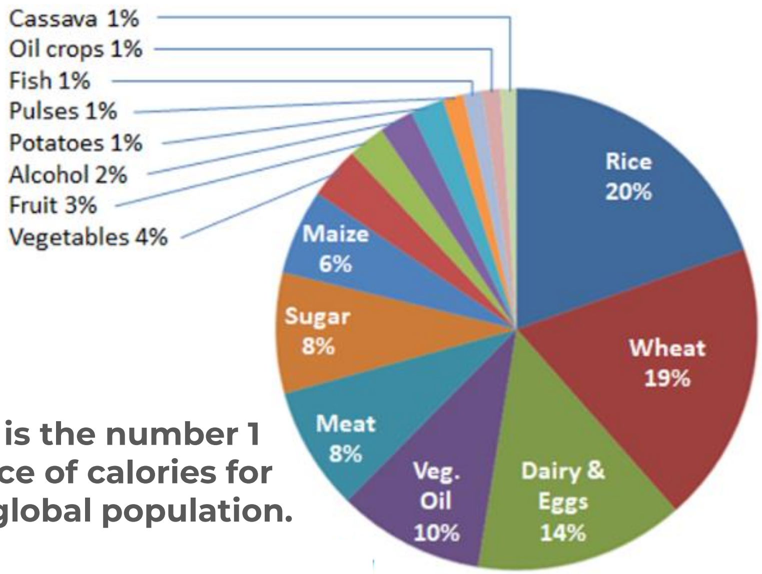
Yearly receives 880 km³ irrigation water
(35% of world total)

CGIAR

IRRI

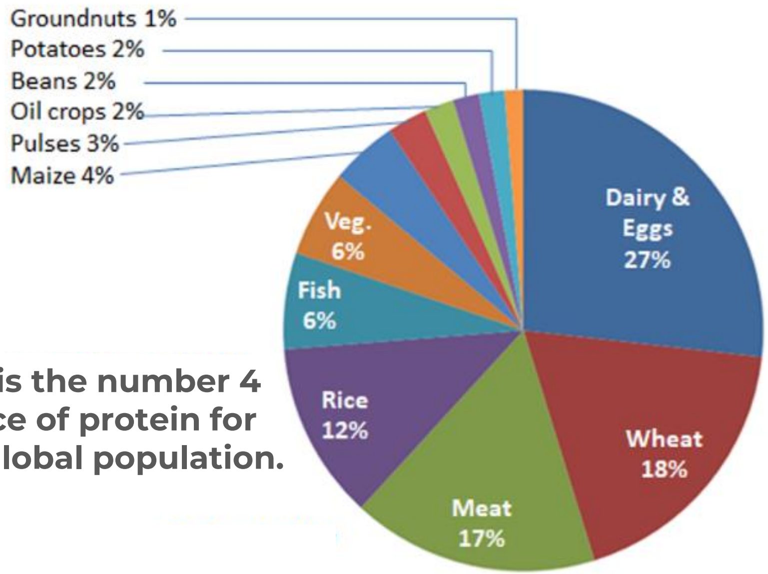
Importance of rice for food security

Global sources of calories



Rice is the number 1 source of calories for the global population.

Global sources of protein

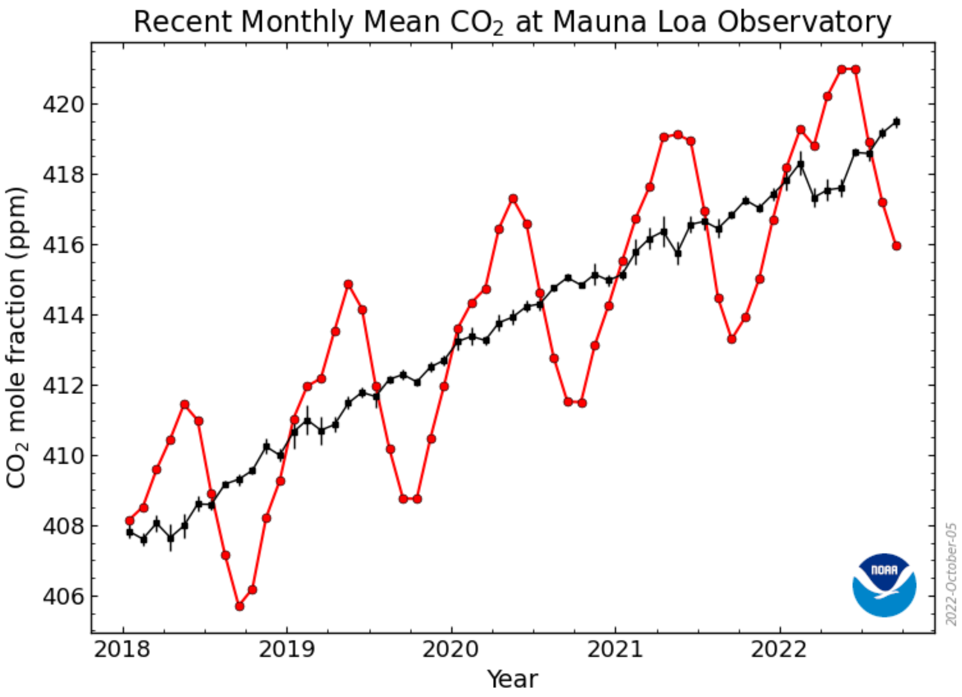


Rice is the number 4 source of protein for the global population.

Source: *FAOstat*

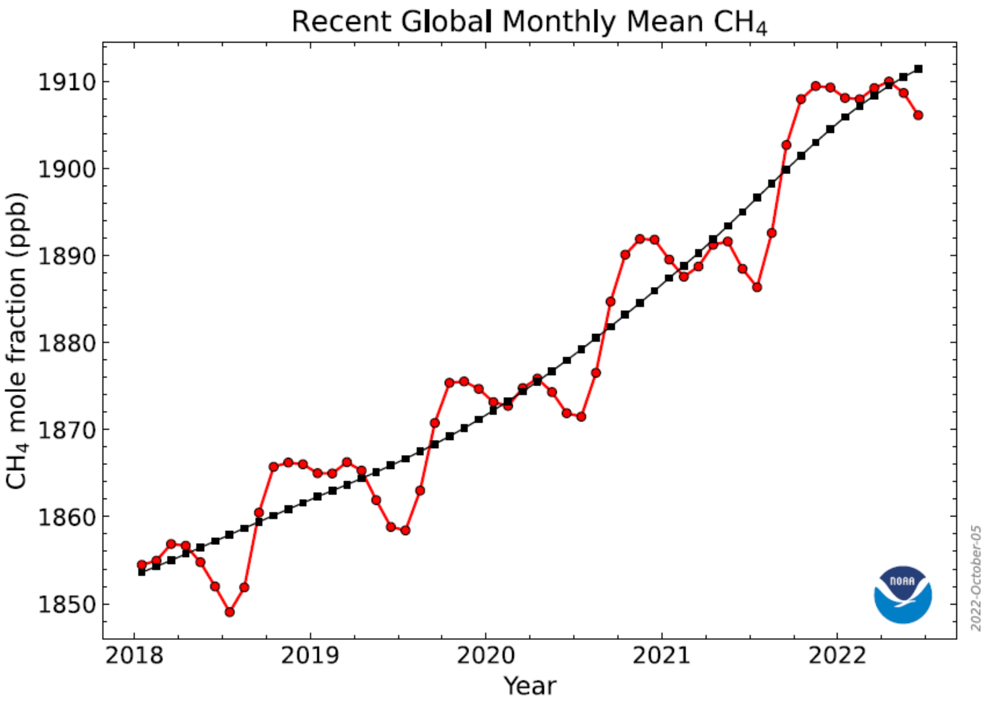
CGIAR IRRI

Atmospheric CO_2 and the 1.5°C target



- The COVID-19 pandemic slowed down CO_2 increase in the past ~2.5 years
- To reach the "1.5°C target", around ~10-100ppm more can be added to the atmosphere
- Scenario (60ppm):
  2020s: 3ppm each year
  2030s: 2ppm each year
  2040s: 1ppm each year
  Neutrality thereafter…

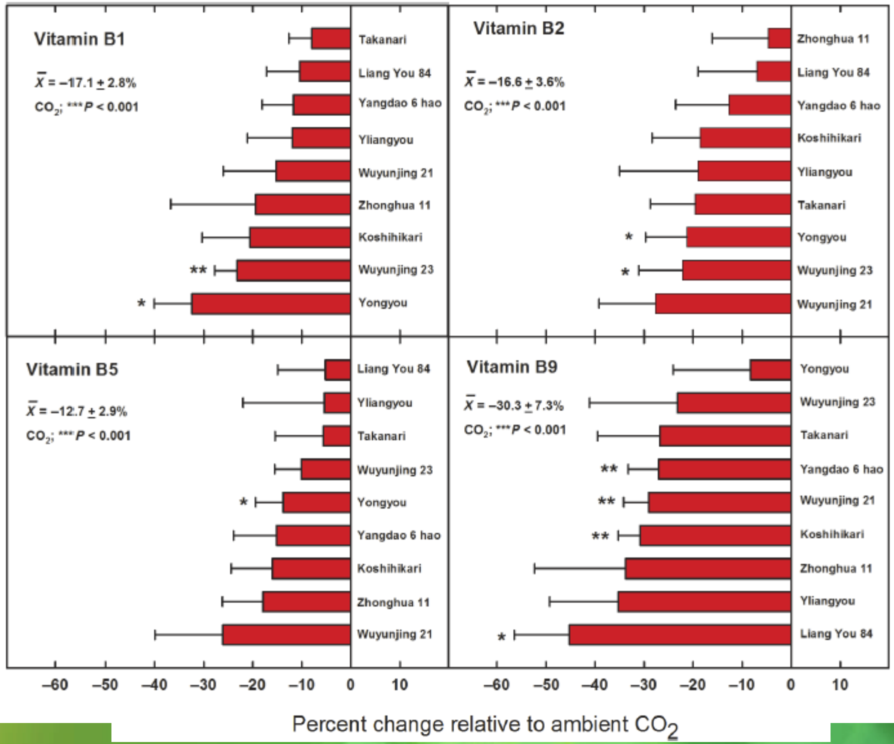
Atmospheric CH_4

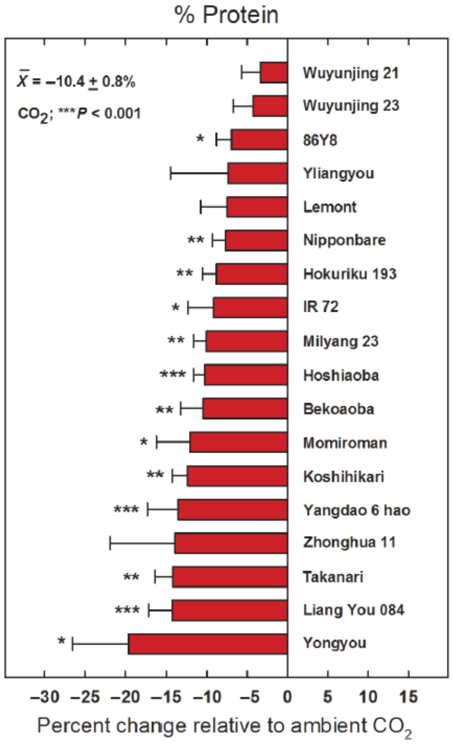


- Average increase 2010-2019: 7.6ppb/yr
- Average increase 2020-2021: 16.7ppb
- Possible reason: La Niña → higher precipitation in tropical regions → higher microbe activity

CGIAR IRRI

Climate Change impacts on grain nutrition





Rice grown in FACE experiments with 570ppm CO_2

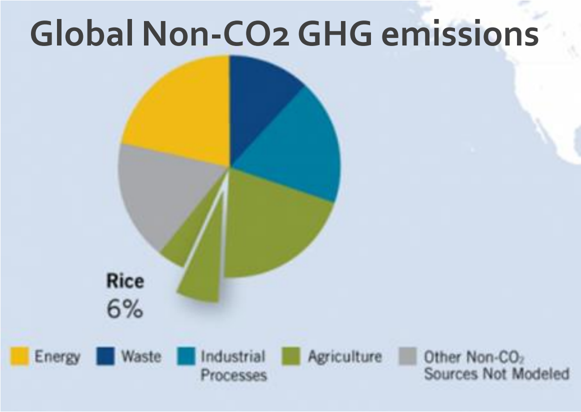
Protein content and many micro-nutrients reduced

Zhu et al., 2018, Science Advances

CGIAR IRRI

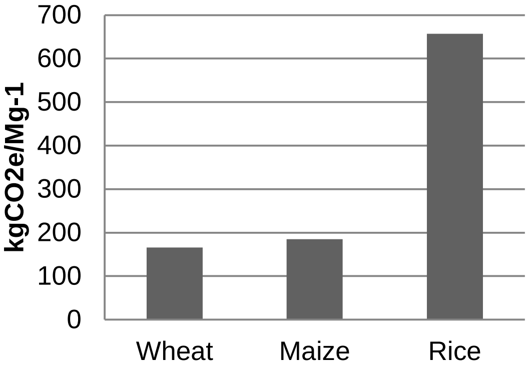
Rice contributes to GHG emissions

- Globally rice, wheat, and maize provide similar amounts of calories and protein
- Yet rice emits significantly more greenhouse gases



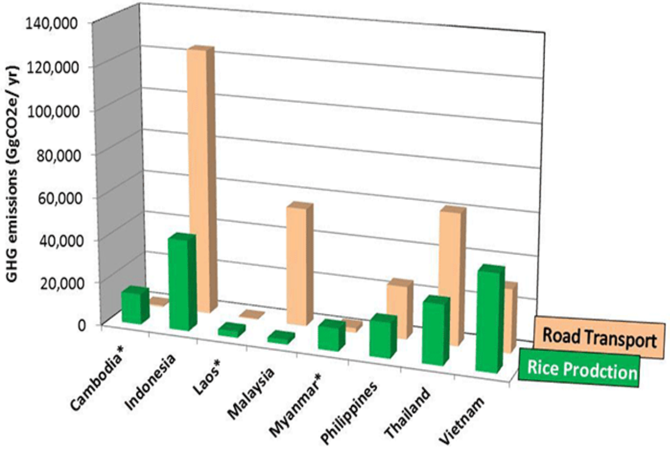
https://19january2017snapshot.epa.gov/global-mitigation-non-co2-greenhouse-gases/global-mitigation-non-co2-greenhouse-gases-rice_.html

Cereal crop GHG emissions



Linquist et al. (2012) Global Change Biology

National GHG budgets (Southeast Asia)

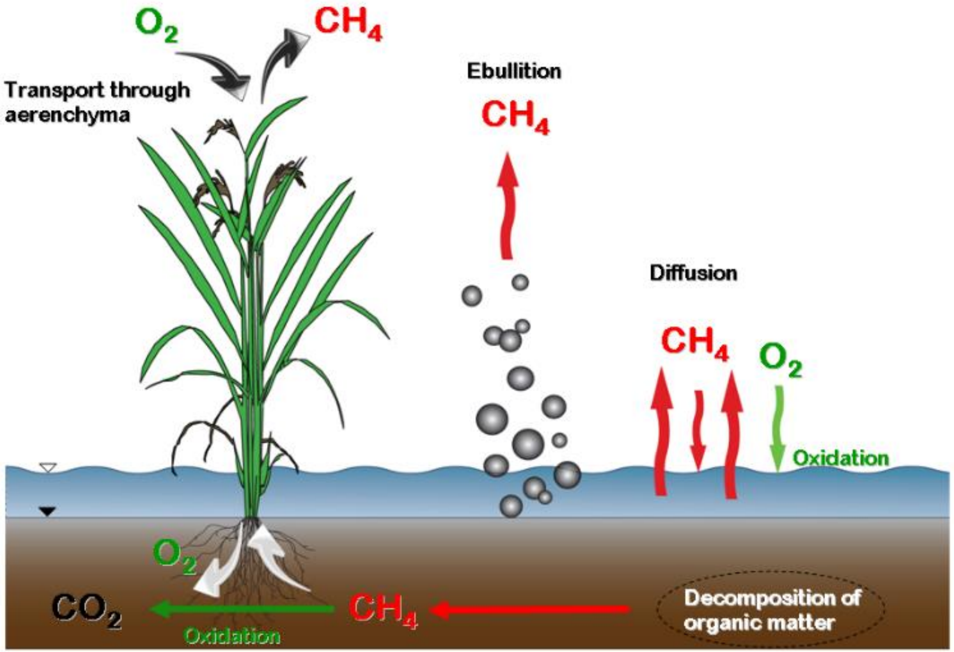


Wassmann (2019), Oxford Res. Encycl.

CGIAR IRRI

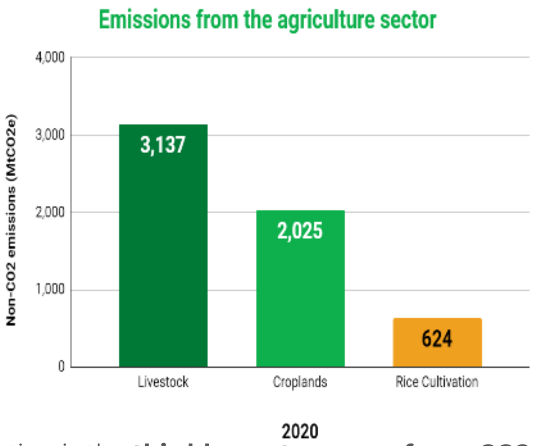
GHG emissions from rice: It's all about Methane!

- ~2/3 of total emissions from rice sector are from paddy soil (CH_4)
- Produced by bacteria in flooded conditions
- High Global Warming Potential (28x more harmful than CO_2) → Priority for mitigation
- Other GHG: N_2O (mostly from fertilization, GWP of 265)
- Carbon sequestration?



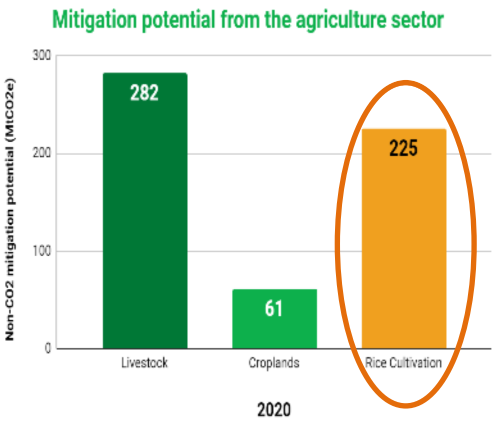
Emission and Mitigation Potential

Net emission is methane plus nitrous oxide minus C sequestration



Globally rice cultivation is the **third-largest source of non-CO2 greenhouse gas emissions** in agriculture, next to livestock and all croplands (EPA, 2021)

This is mostly due to the traditional method of paddy farming, where **flooded fields release methane** and other greenhouse gases through anaerobic decomposition



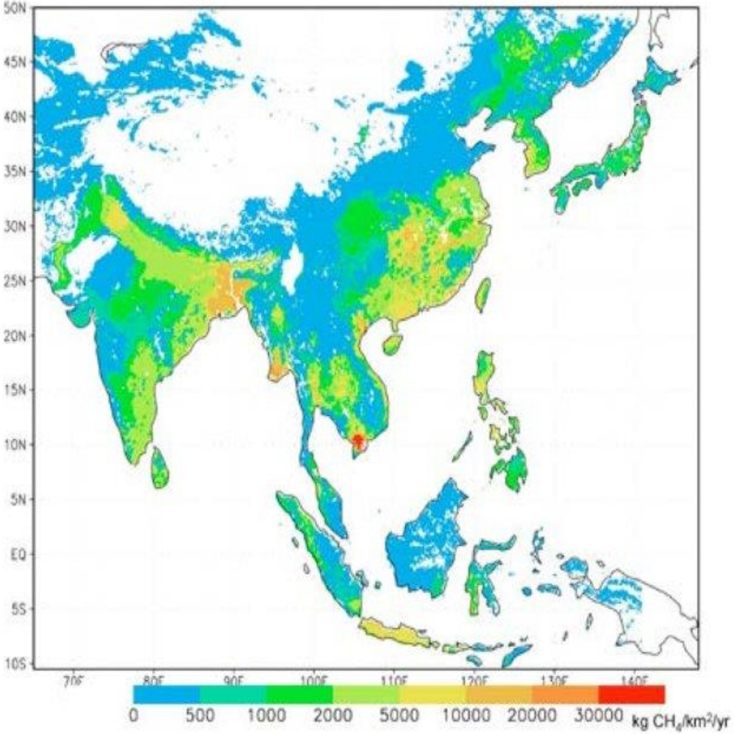
However, the relative **mitigation potential for rice (36%)** is much higher than that of livestock (9%), and croplands (3%) (Roe et al., 2021; EPA, 2021)

Promising options for rice!

In the entire agriculture sector, paddy rice production offers one of the most promising options for reducing absolute emissions

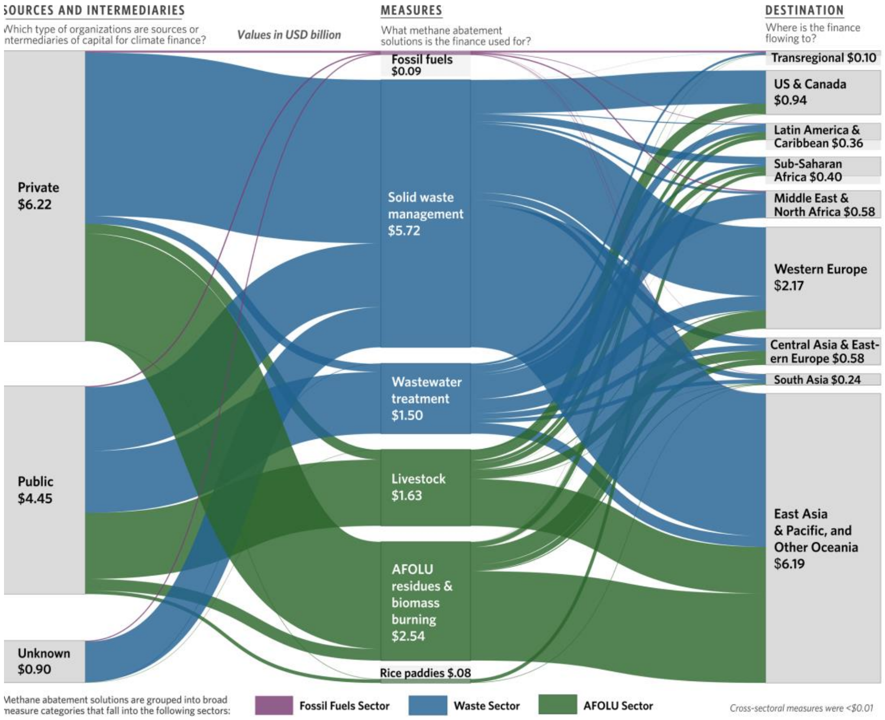
Current emission baselines are high, particularly in Asia, but:

- Many established emission reduction practices available – new ones ‘in the making’
- Multiple outscaling approaches with both public and private sector parties
- Powerful new drivers:
  1) Paris Agreement 2015, Global Methane Pledge 2021
  2) Potential rice carbon credit markets



Source: Yan et al., 2009

Global targeted methane abatement finance flows in 2019/2020



- Investments for methane reduction are geared towards waste management/ wastewater treatment, followed by livestock and residue burning

- Investments in GHG abatement in rice is very low compared to the mitigation potential

Climate Policy Initiative, 2022,
The Landscape of Methane Abatement Finance

CGIAR IRRI

Existing mitigation options across the rice production cycle

can reduce as much as 65% - mostly methane

UP TO 10%

***Timing* of residue incorporation in field**

UP TO 7%

Planting short-duration rice varieties

Average 33%

Alternate Wetting & Drying, Efficient use of fertilizer

UP TO 15%

***Amount* of residue left after harvest, no straw burning**

Different **rice cultivars** have different CH_4 emission potentials

Water-saving technologies adapting rice production to climate change while reducing emissions

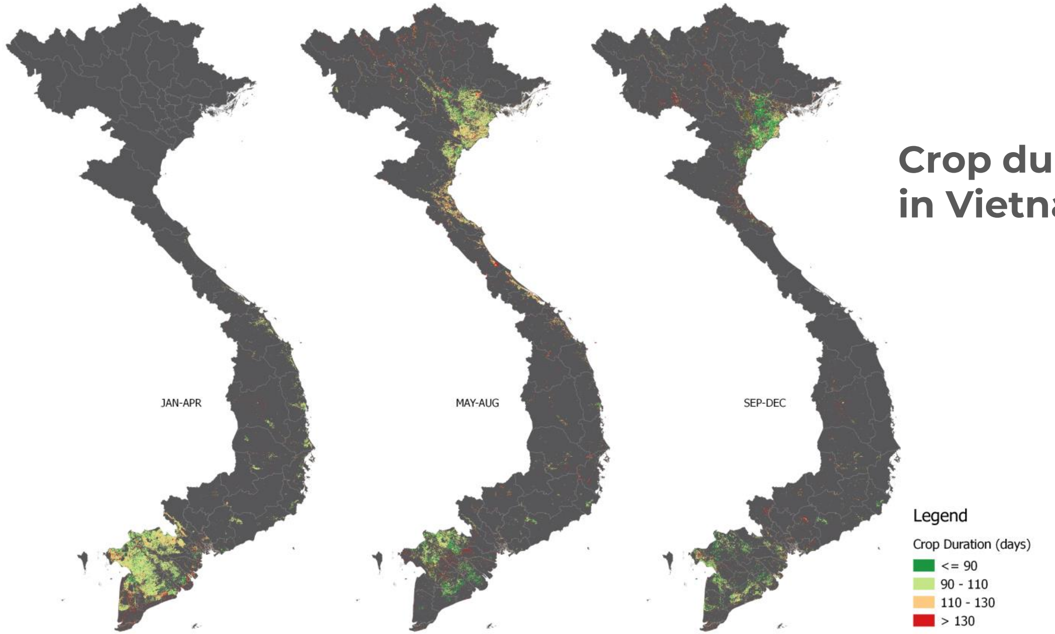
a) Mushroom production for a nutritious, profitable product

b) Mechanized composting to produce organic fertilizer

CGIAR

IRRI

...but
a) Some technologies have reached their potential already



Crop duration in Vietnam

PhenoRice analysis for Vietnam shows that short-duration varieties are the standard practice

Boschetti et al., 2017, Remote Sensing of Environment

...but
b) Many technologies have (market) barriers

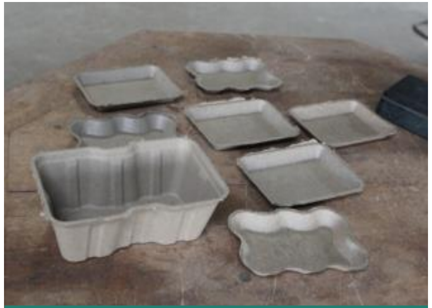
- Balers are crucial for valorization of rice straw, can only be used in dry conditions
- Products need markets and market access
- Innovative uses of rice straw can reduce burning and emissions while providing additional income to farmers

Roller baler pulled by a tractor

Anaerobic digestion of straw for biogas
Source: Ngan N.V.C. et al. (2020)

Straw mushroom production
Source: Thuc L.V. et al. (2020)

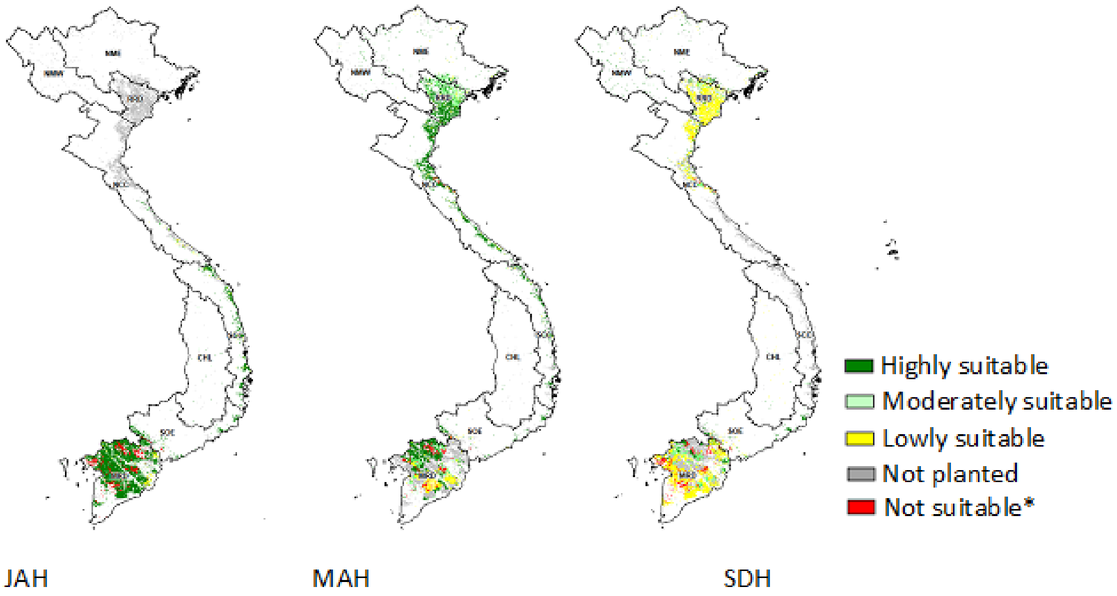
Mechanized composting
Source: Hung et al. (2019)



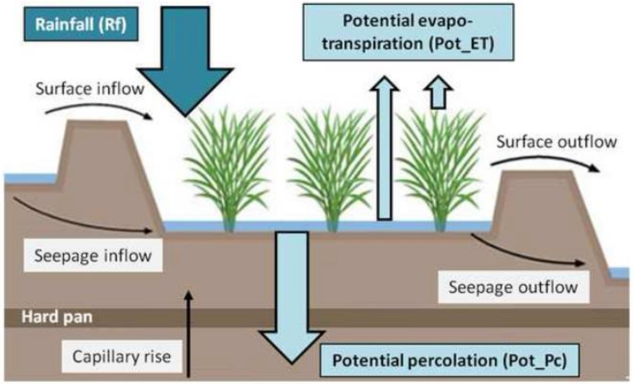
Bio-plastics

CGIAR IRRI

...but
c) Not all technologies can be applied everywhere at all times



Climatic suitability for water-saving technologies in rice



Vietnam Example :
The very ambitious NDC plans for GHG mitigation in rice may reduce ~18% of total rice emissions

Sander et al., 2022, manuscript in preparation
Sander et al., 2017, Carbon Management
https://www.eastasiaforum.org/2022/05/14/

CGIAR IRRI

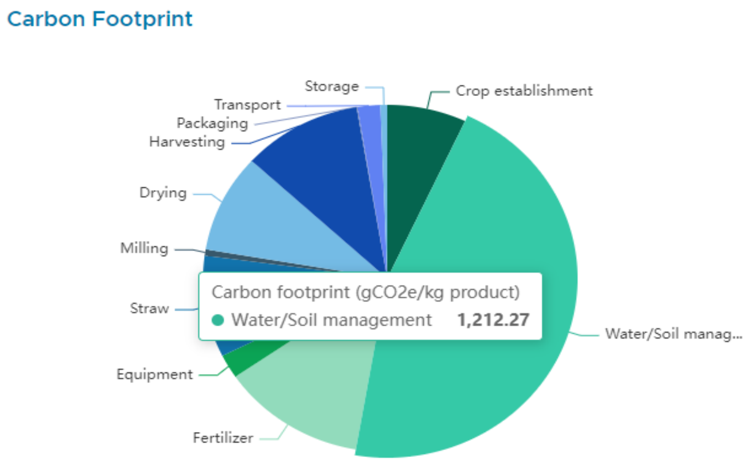
Adoption enabler: Monitoring, Reporting, and Verification (MRV) tools

SECTOR — **Simple and flexible GHG calculation tool based on the IPCC approach for rice; part of Thai rice MRV**

CF-Rice — **Carbon Footprint assessment of rice value chains, food loss calculator**

COMPARE — **Cost-impact analysis for emission reduction projects**

RiceMo — Broad-scale farm activity monitoring tool *(under development!)*



Example output

GHGmitigation.irri.org

CGIAR IRRI

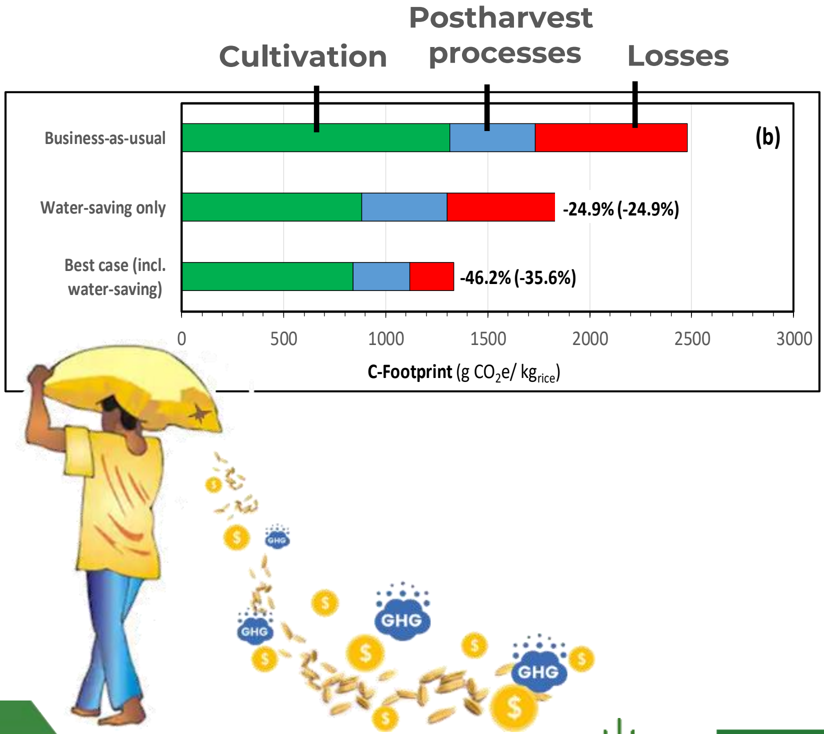
Adoption enabler: Efficiency gains to reduce the carbon footprint and engage private sector

Losses are unnecessary emissions

- Convert losses into equivalent GHG emissions
- Calculate the economic value of the losses
- Win-win: More efficient value chain, lower C-footprint

Carbon Footprint reduction

- Increasing efficiency reduces the relative emissions per grain
- Assessing the economic and climate impacts of improved cultivation and post-harvest practices along the rice value chain



CFrice.irri.org

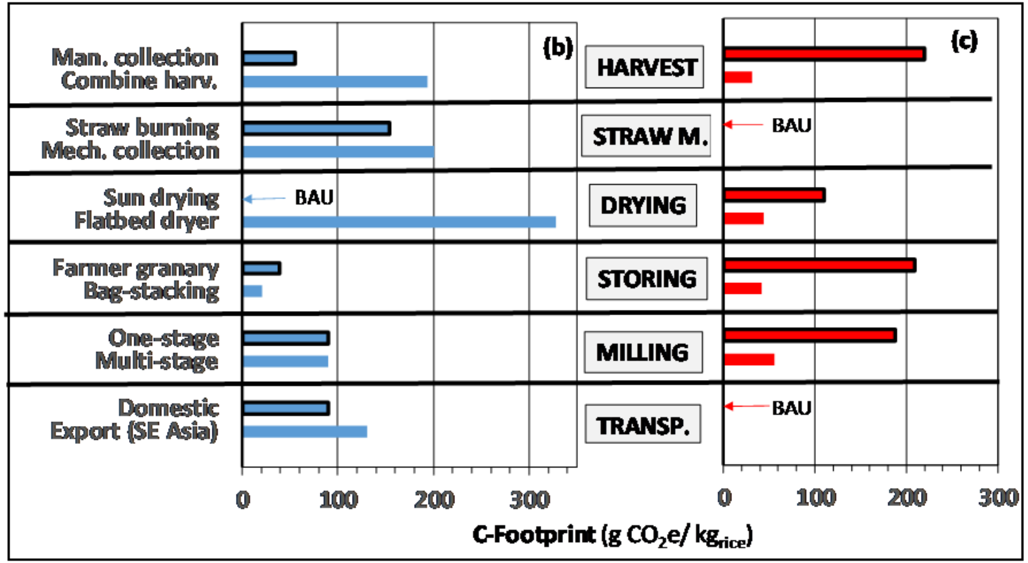
CGIAR

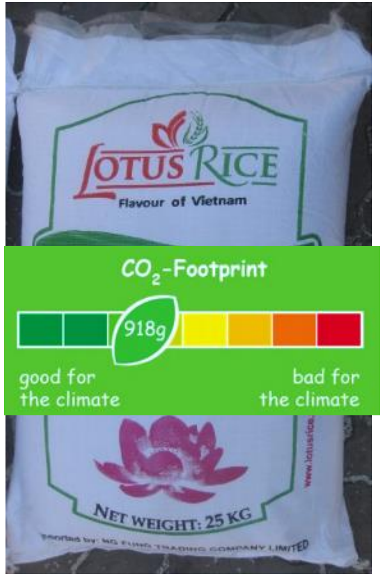
IRRI

Emissions and losses at different steps of the rice value chain

CF-Rice

- Different technologies are associated w/ different amounts of GHGs (blue) and losses (red)





CFrice.irri.org

CGIAR

IRRI

Adoption enabler: Methodology for carbon credits from low-emissions rice production

Clean Development Mechanism (CDM) methodology for accreditation of carbon credits for adjusted water management in rice: *AMS-III.AU*

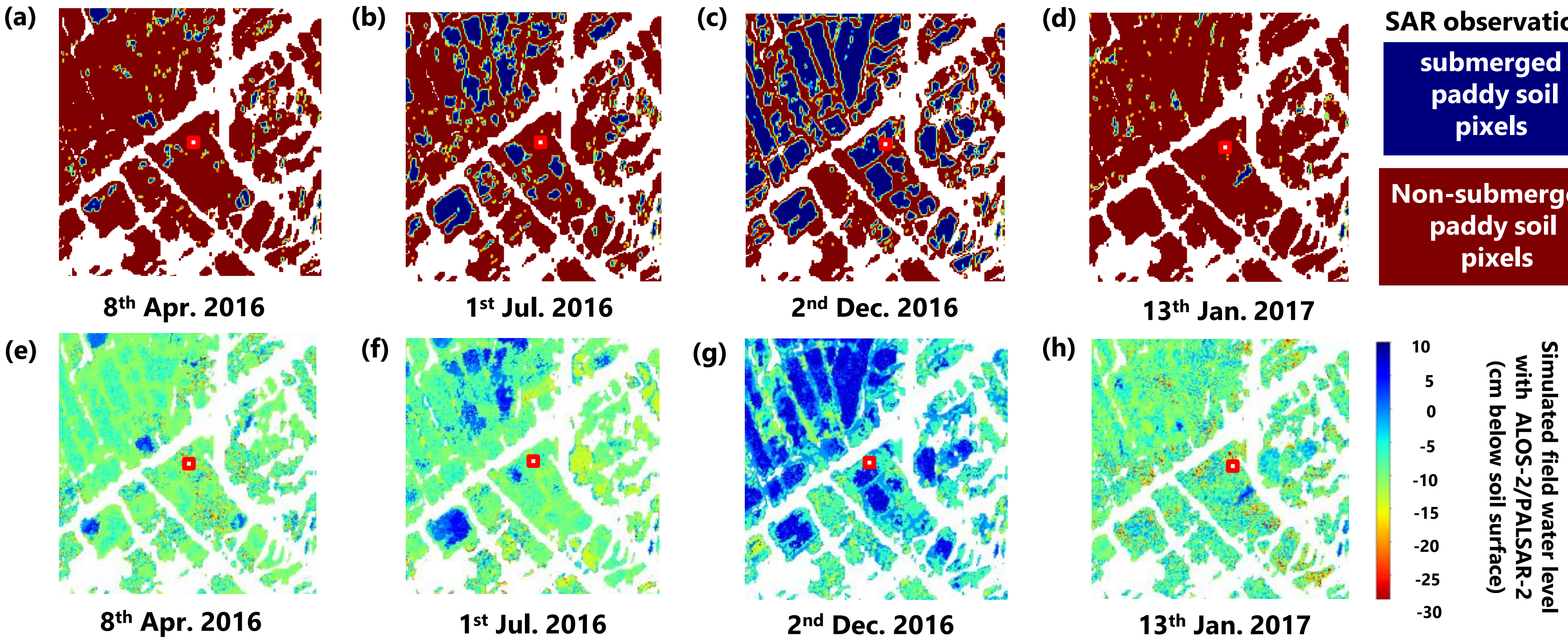
- IRRI-developed CDM methodology is accepted by voluntary markets
- Feasibility in small-scale systems
- Has undergone several rounds of revision to make it more usable
- No credits have been granted yet using this methodology

Many open questions...

- Minimum size of a C credit project for economic viability?
- Pay-out modes? How do farmers benefit?
- Accuracy?
- Mitigation options beyond water-management?
- Carbon credits *vs.* countries' NDCs?
- …

CGIAR IRRI

Adoption enabler: Remote sensing for activity data monitoring



Note

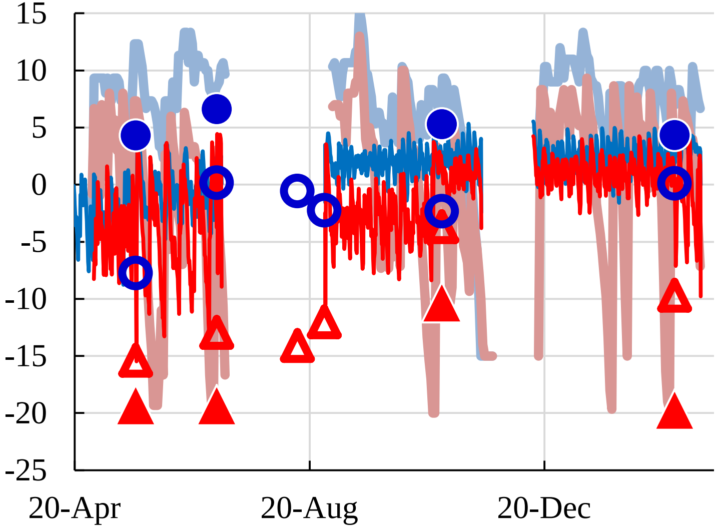
Lite blue: Not submerged (i.e., water level is lower than 0)

Blue: submerged (i.e., water level is taller than 0)

Arai et al., 2022, Remote Sensing of Environment
Arai et al., 2022, IGARSS

CGIAR IRRI

Adoption enabler: Simulating water levels and GHG emissions



Ground-observed field waterlevel

Continuously inundated paddy

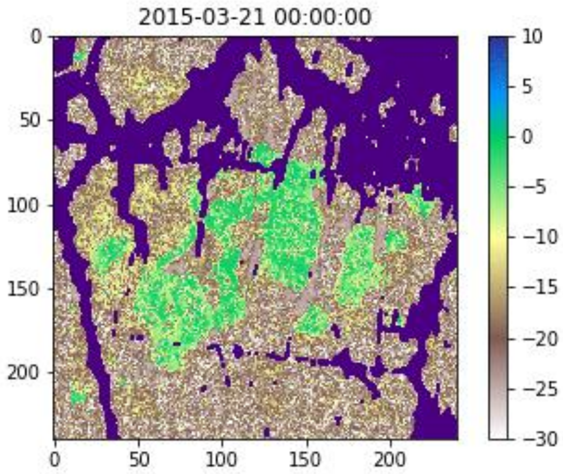
Paddy with intermittent drainage

Mean values of simulated field water level (4×4 pixel windows around the ground observation point)

Continuously inundated paddy

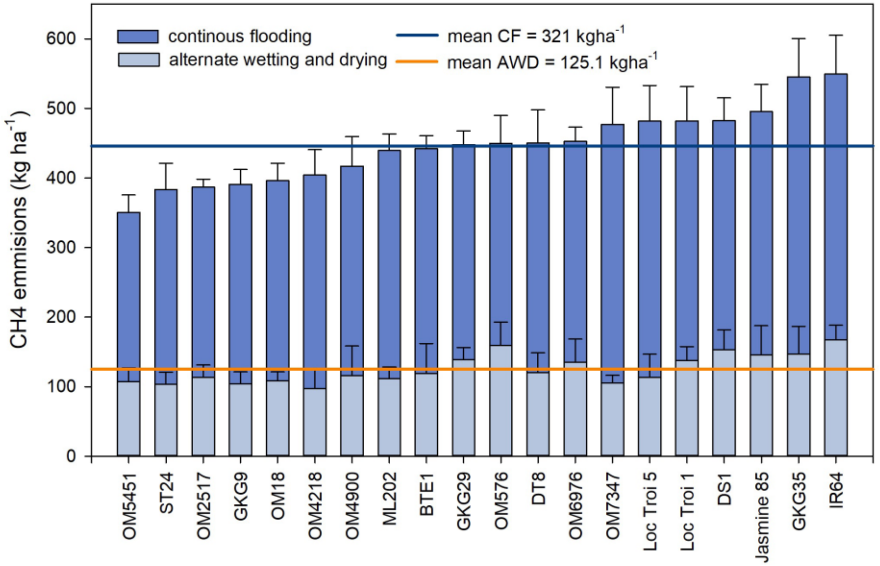
Paddy with intermittent drainage

Simulated field water level (cm below soil surface)



CGIAR IRRI

New frontiers: Identifying low-emission rice varieties



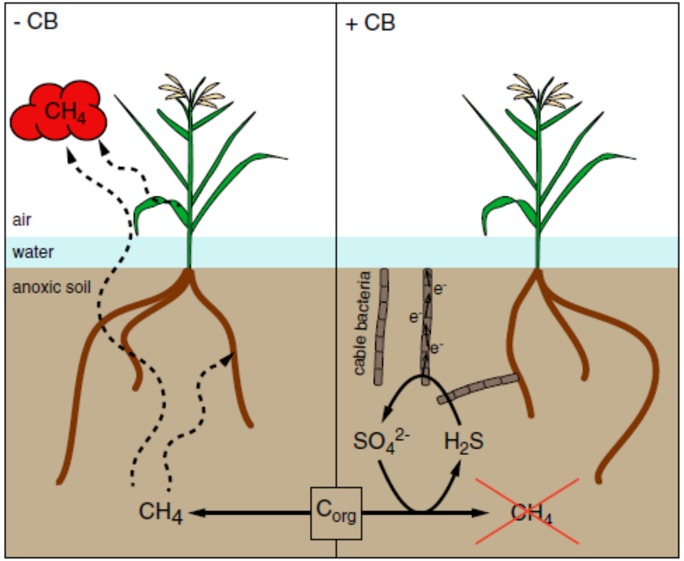
Vo et al., 2022, manuscript in preparation
See poster for more details

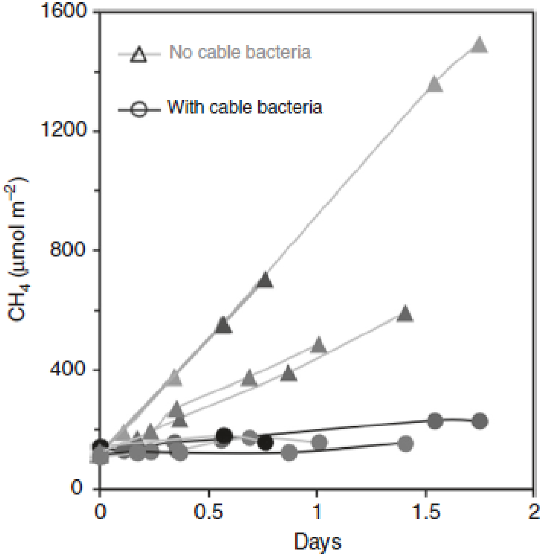
Field experiment of Hohenheim University and IRRI in Vietnam

CGIAR IRRI

New frontiers: Limiting methanogenesis

- example: Cable bacteria





- Cable bacteria oxidize sulfide to sulfate
- Sulfate is reduced before org. C
- Sulfate-reducing bacteria outcompete methanogens

Impact pathway for rice climate change mitigation

Upstream and adaptive research

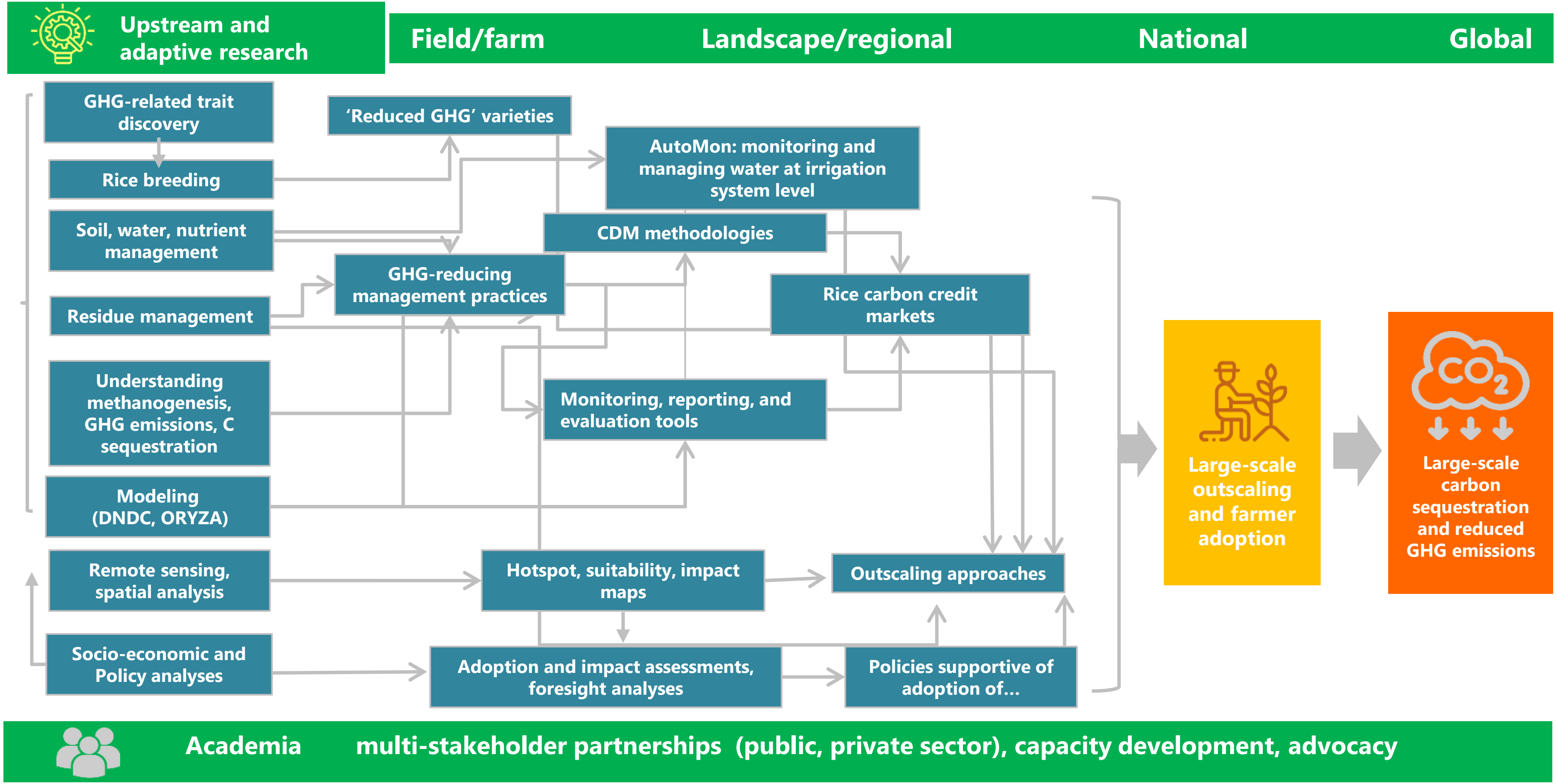
Field/farm | **Landscape/regional** | **National** | **Global**

control → influence → interest

- **Large-scale reduced GHG emissions**
- **Outscaling and farmer adoption**
- **Adoption enabler:** Conducive policies
- **Adoption enabler:** Capacity development, training
- **Adoption enabler:** Rice Carbon Credit Markets
- **Adoption enabler:** Monitoring, Reporting, Validation (MRV) tools
- **Technologies and management practices**
  Farm – landscape/irrigation system level
- **Discovery research**

Academia **multi-stakeholder partnerships (public, private sector), capacity development, advocacy**

CGIAR IRRI


Upstream and adaptive research
Field/farm
Landscape/regional
National
Global
GHG-related trait discovery
Rice breeding
Soil, water, nutrient management
Residue management
Understanding methanogenesis, GHG emissions, C sequestration
Modeling (DNDC, ORYZA)
Remote sensing, spatial analysis
Socio-economic and Policy analyses
'Reduced GHG' varieties
AutoMon: monitoring and managing water at irrigation system level
CDM methodologies
GHG-reducing management practices
Rice carbon credit markets
Monitoring, reporting, and evaluation tools
Hotspot, suitability, impact maps
Outscaling approaches
Adoption and impact assessments, foresight analyses
Policies supportive of adoption of…
Large-scale outscaling and farmer adoption
CO2
Large-scale carbon sequestration and reduced GHG emissions
Academia
multi-stakeholder partnerships (public, private sector), capacity development, advocacy

CGIAR IRRI

Conclusions

- Rice is the most important food crop globally
- Rice contributes to Global Warming
- But: tremendous opportunities for mitigation of GHGs!
- Clear impact pathway is necessary for large scale impact
- More investment is needed in rice methane abatement

CGIAR IRRI

Thank You!