Mitigation of Greenhouse Gas Emissions From Agricultural Lands by Optimizing Nitrogen and Carbon Cycles

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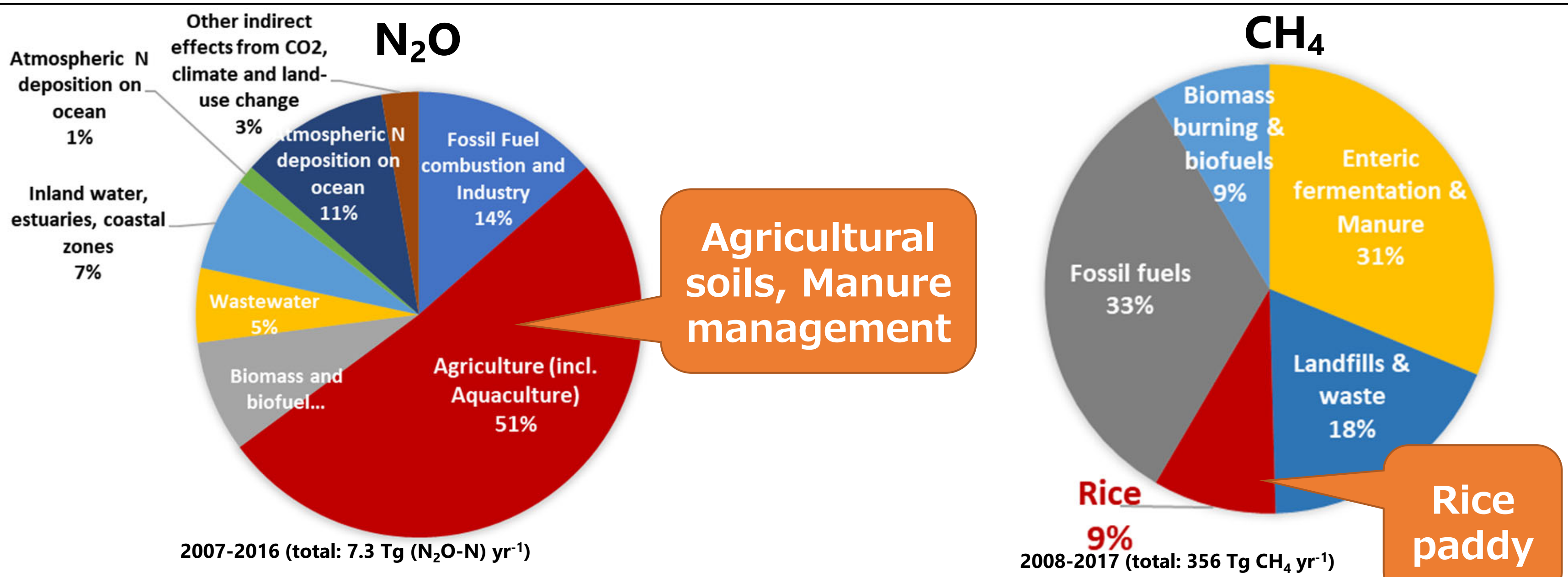
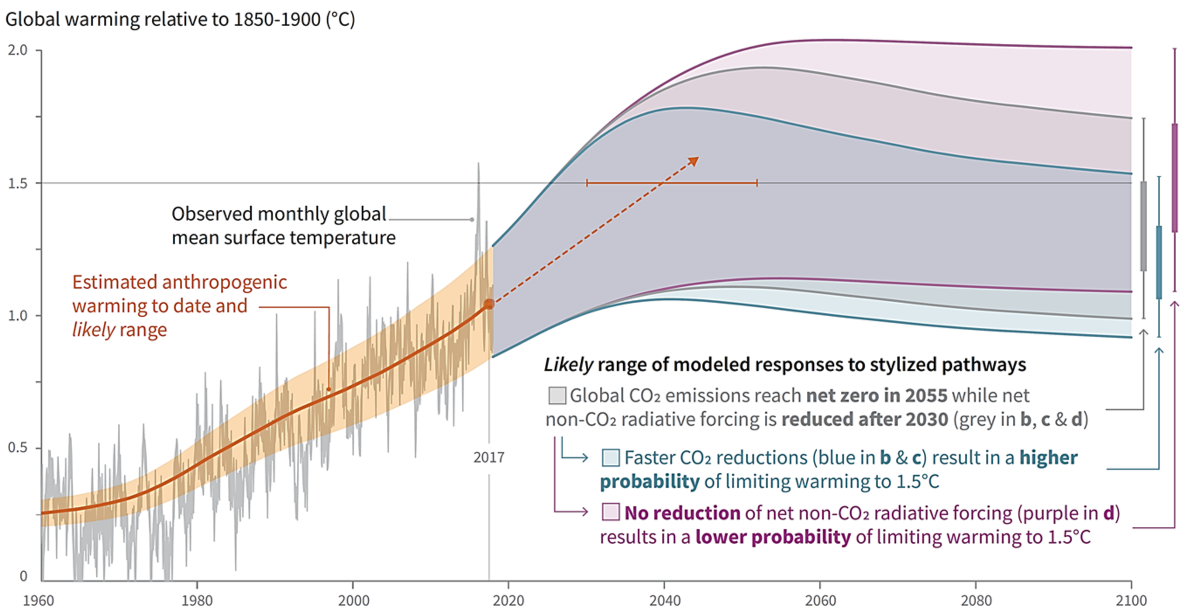
National Agriculture and Food Research Organization (NARO)

Agriculture: Major Anthropogenic Source of N_2O & CH_4



Anthropogenic sources of N_2O and CH_4 (IPCC-AR6 WG1, 2021)

In addition to CO_2 reduction, the reduction of N_2O and CH_4 is needed, to limit global warming to 1.5 ℃



(IPCC SR1.5℃, 2018)

Research Goal

Challenges:
Understanding of microbial habitats
Use of target microbes in the environment

2050

N_2O: 80% mitigation from agricultural soil
CH_4: 80% mitigation from paddy rice fields

Standardization of mitigation technologies — **2029** — **Field tests 80% mitigation**

Bench scale tests — 2027 — **Bench scale tests of microbial GHG mitigation and new plants**

Field tests 30% mitigation
Lab tests 80% mitigation
patents
— 2024 — Microbial GHG mitigation and breeding of new plants

2022 — Microbes with high N2O reductase activity
New nitrification inhibitors
Methane-oxidizing diazotrophs

2020 — **Soil microbes: 99% unknown**

COP26 Global Methane Pledge in 2021
Reduction of 30% of CH_4 in 2030

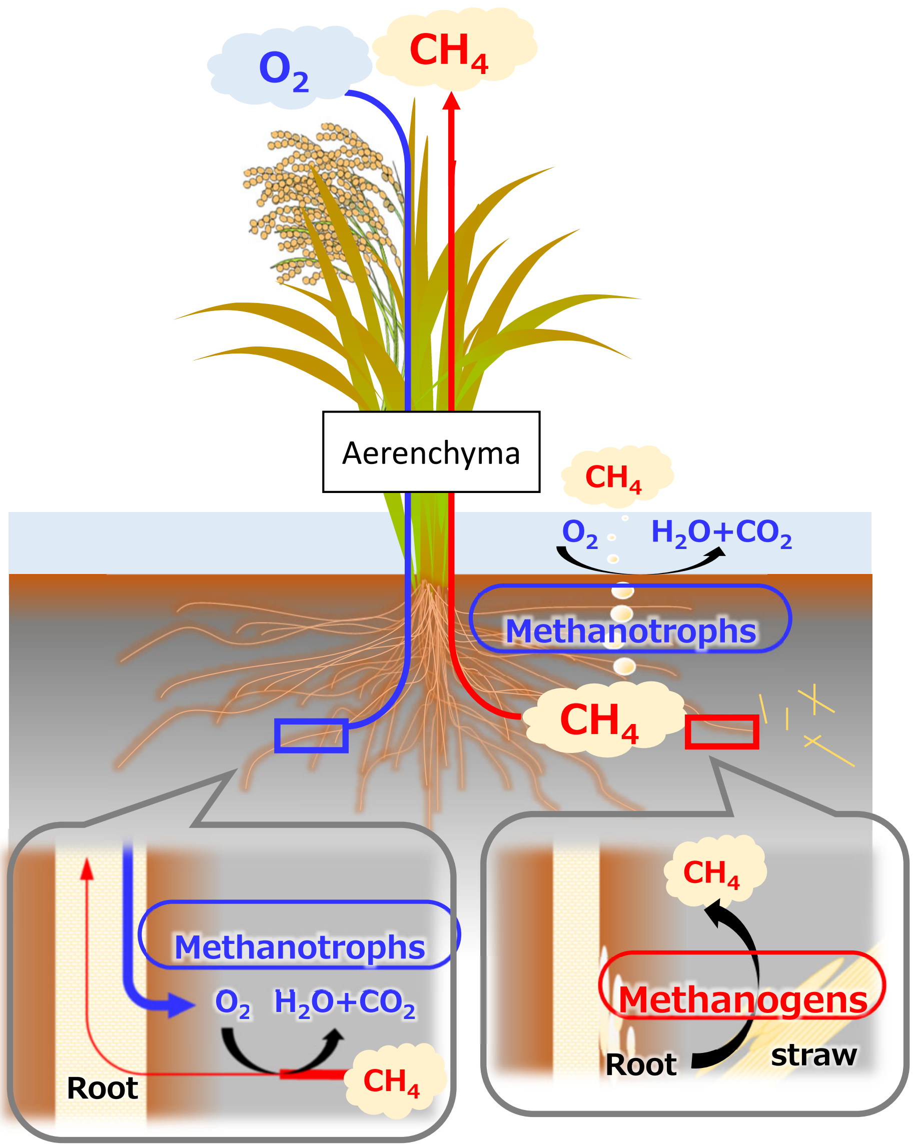
COP26: US and EU announce global pledge to slash methane

Joe Biden says COP26 methane reduction pledge will make "huge difference"

Over 100 nations joined

Why is CH_4 reduction important ?
・Short lifetime in the atmosphere (12 years)
→ Rapid CH_4 reduction is the single most effective strategy to keep the goal of limiting 1.5℃

Mitigation options for CH_4 emission from paddy rice fields



CH_4 production

- Anaerobic decomposition of organic material by methanogens

CH_4 oxidation

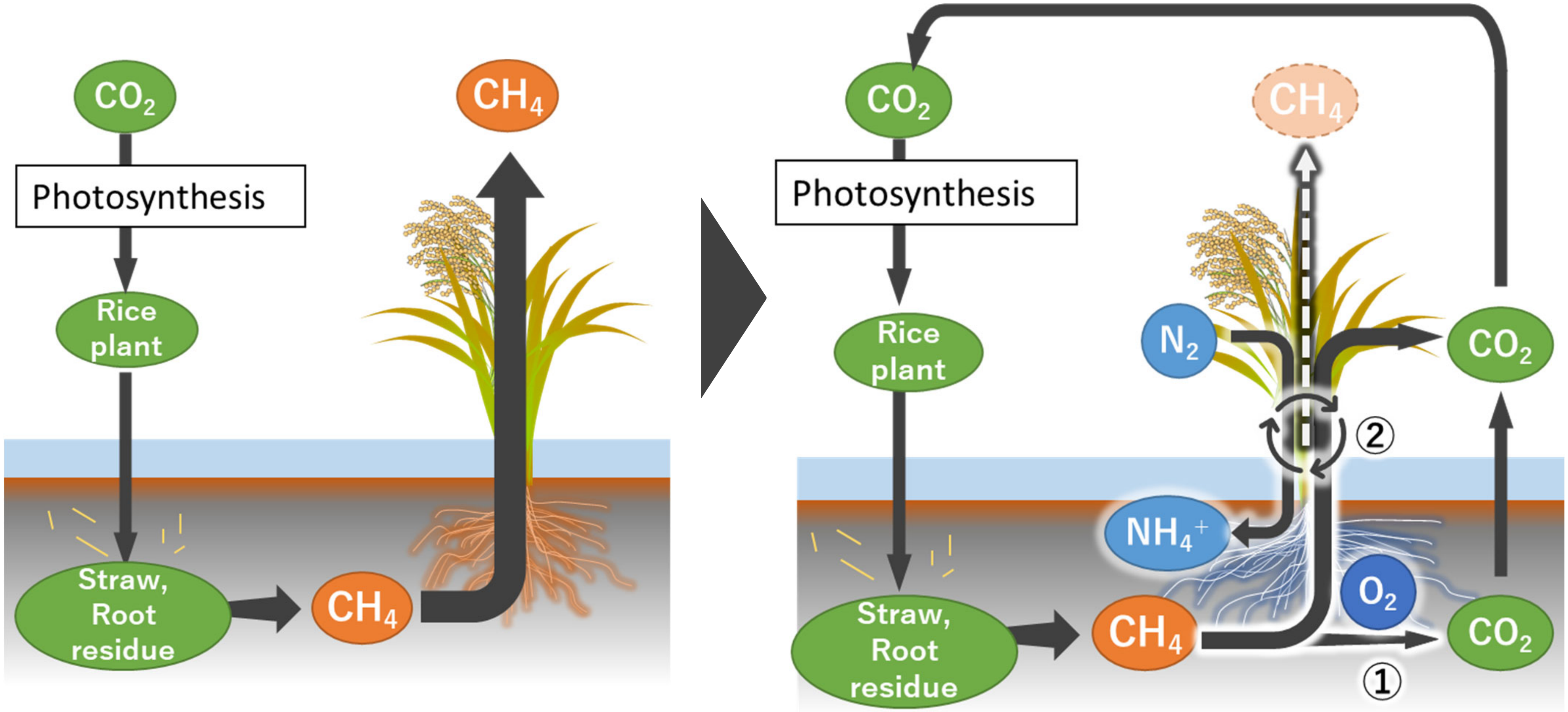
- rhizosphere of rice roots, soil-floodwater interface by methanotrophs

Well-studied mitigation options:

- Water management (prolonged mid-season drainage)
- Straw management (incorporation after harvest, instead of before planting)

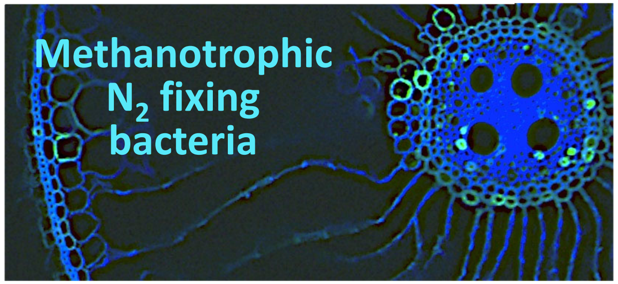
MS project:

New Mitigation Strategies for CH_4 Emission



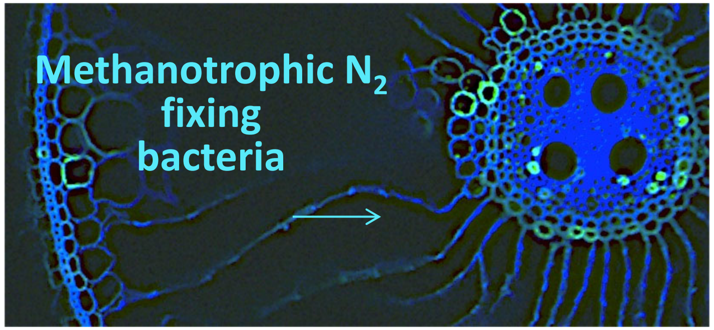
1. Enhance CH_4 oxidation by breeding of new rice varieties

2. Enhance CH_4 oxidation by methanotrophic N_2 fixing bacteria



Bao et al., 2014

Strategies of reduce CH_4 emission

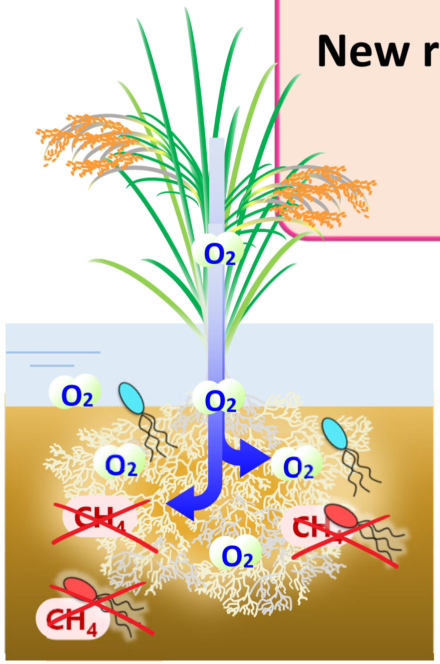


Bao et al., 2014

methanotrophic N_2 fixing bacteria

40%

New rice varieties
40%



Prolonged mid-season drainage, straw management
40%

Well-studied mitigation options

80%
mitigation

80% reduction of CH_4 emission from rice paddy fields

CH_4 reduction by new rice varieties

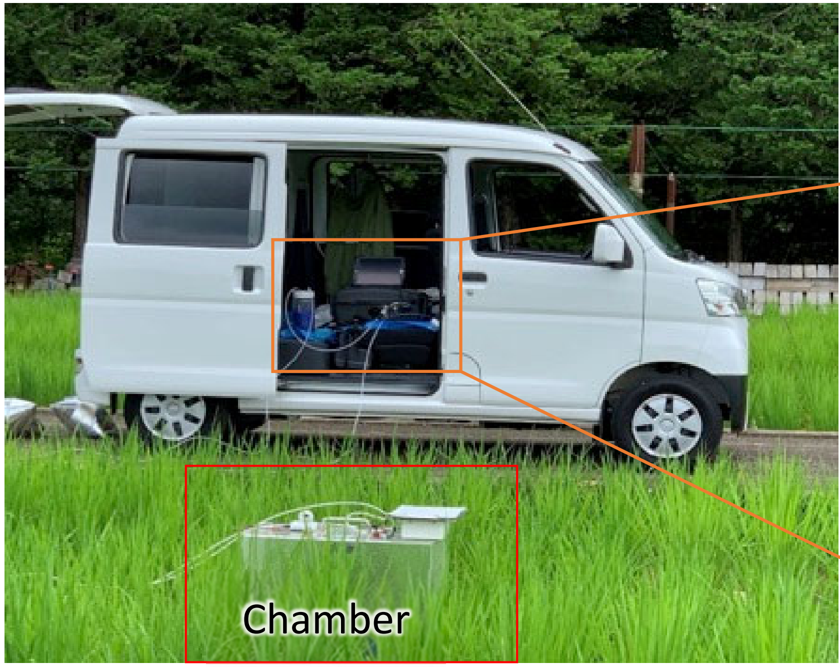
Development of high throughput CH_4 flux measurement

Genetic resource of rice (NARO)

Screening of low CH4 rice varieties to breed new rice varieties

- **Breeding new commercial rice varieties with low CH_4 emission**

High throughput CH_4 flux measurement by using mobile CH_4 analyzer (Picarro G4301)



Tokida 2021 J. Agric. Meteorol.

■Chamber closure time

Babble (time/min)	Closure time (min)
0	4
0.5	6
1.0	8
1.5	10
2.0	13
2.5	15

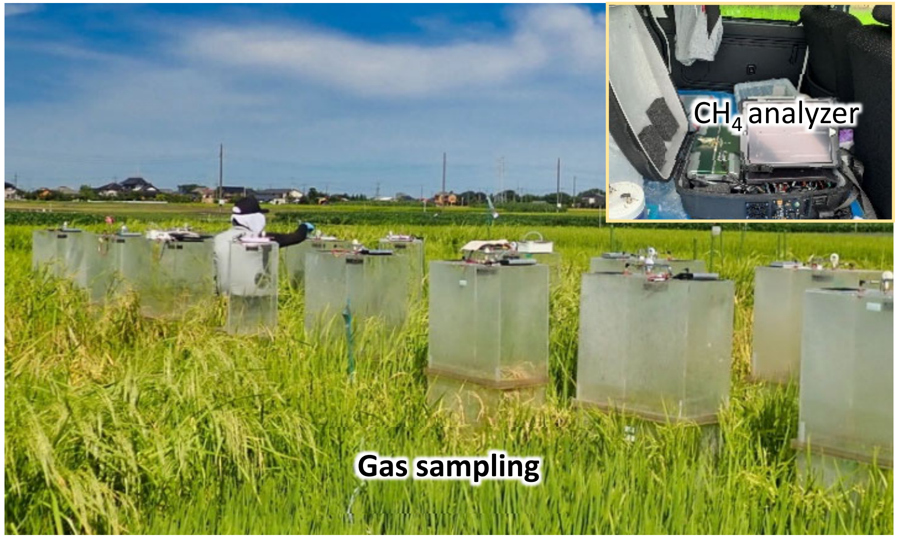
GC method: 45 min

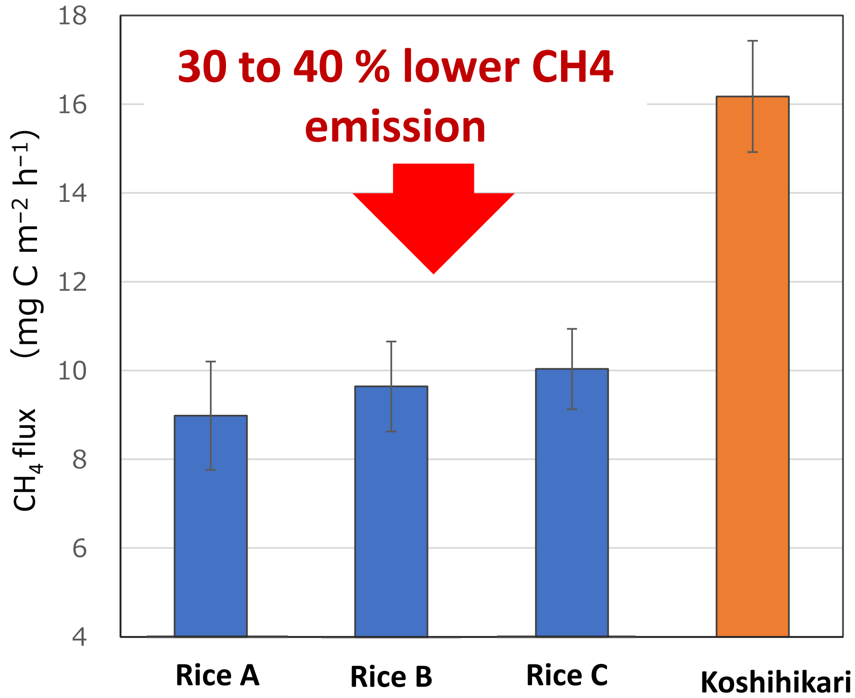
Gas sampling (30 min) and GC analysis (15 min)

→New method: 15 min （1/3）

Kajiura & Tokida, 2021b, J. Agric. Meteorol.(in press)

Genetic source of rice varieties with low CH_4 emission

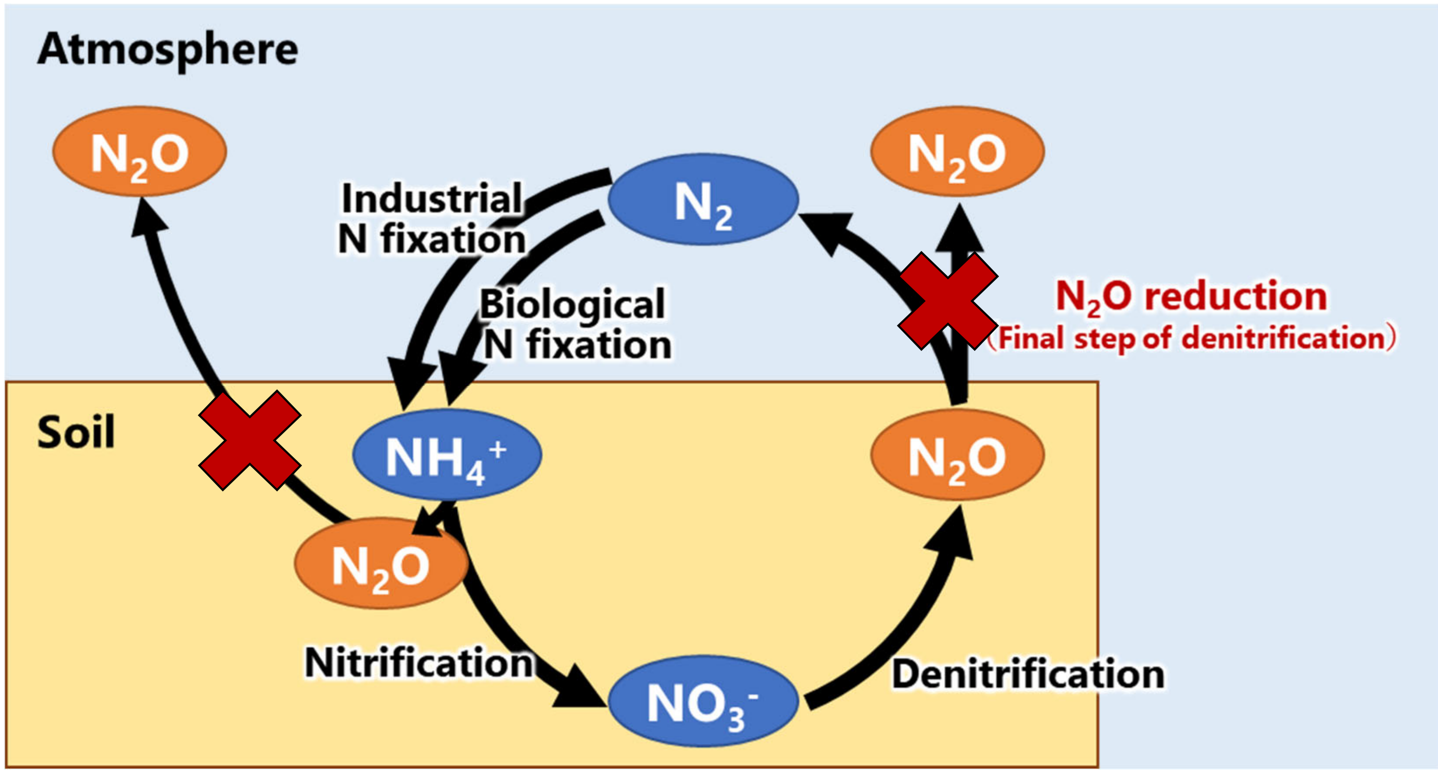




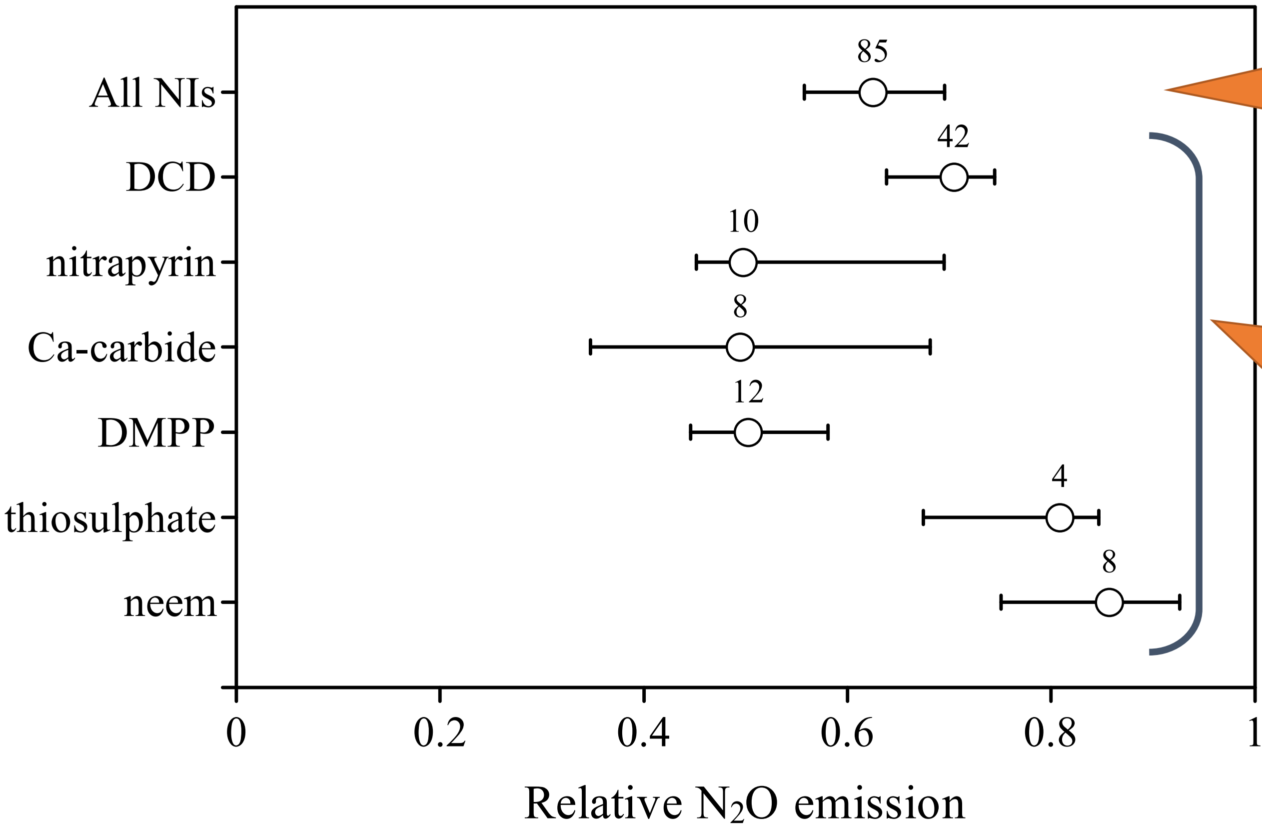
→Breeding new commercial rice varieties with low CH_4 emission

Development of new inhibitors to mitigate N_2O

- ✓N_2O production processes: nitrification & denitrification
- ✓Develop new nitrification and denitrification inhibitors to reduce N_2O emission



Meta-analysis:
Effect of NIs on N_2O emissions



Mean effect of all NIs:-38%

All types of NIs: effective

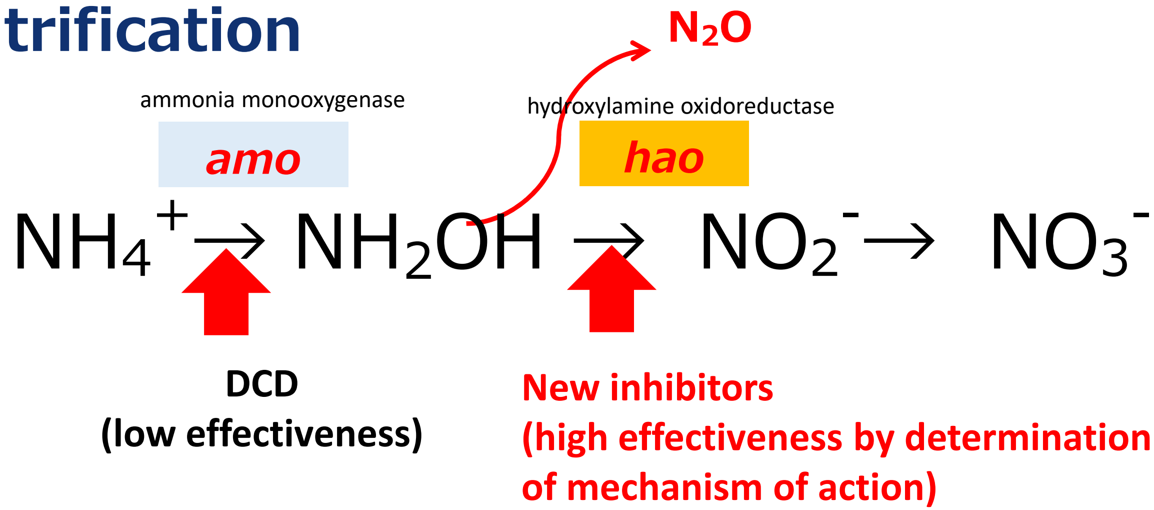
- Conventional fertilizer = 1
- Mean effect & 95% CIs
- Numerals: number of observations

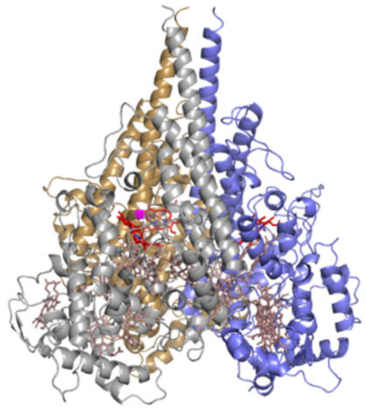
Akiyama et al., 2010

1: Nitrification inhibitor targeting HAO

- Selected 287 candidate chemicals
- Started to determine the mechanism of action

Nitrification





HAO
(ours)

2: Denitrification inhibitors targeting NirK

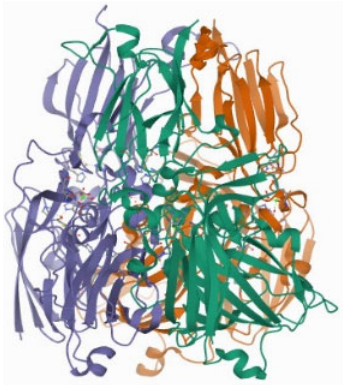
- Soil metagenome analysis to select target NirK in soil
- Started screening of candidate chemicals inhibit NirK

Denitrification

nitrate reductase	nitrite reductase	Nitric oxide reductase	Nitrous oxide reductase
nar	***NirK***	***nor***	***nos***

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow \mathbf{N_2O} \rightarrow N_2$

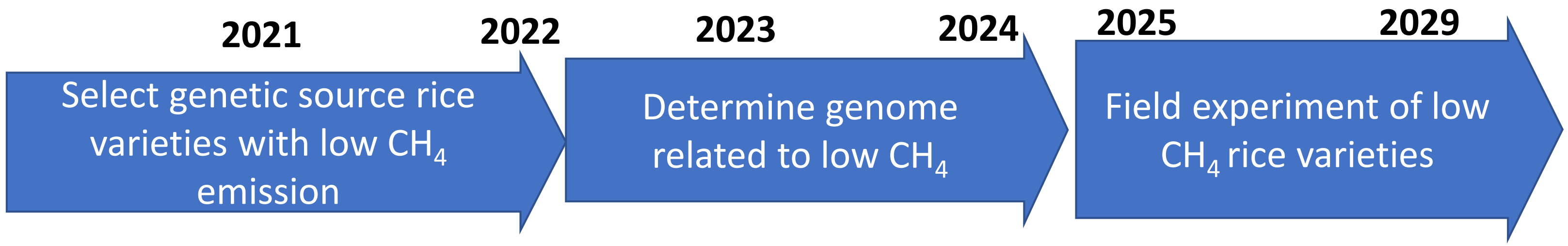
New inhibitors
(high effectiveness by determination of mode of action)



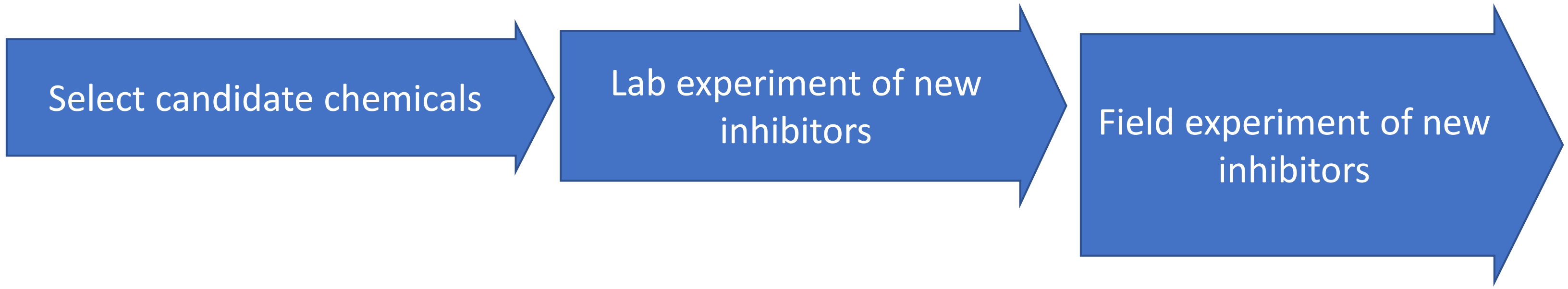
NirK
(6HBE)

Goal in 2050
80% reduction of N_2O from agricultural soils
80% reduction of CH_4 from rice paddy fields

New rice varieties with low CH_4 emission



New inhibitors to reduce N_2O emission



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