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

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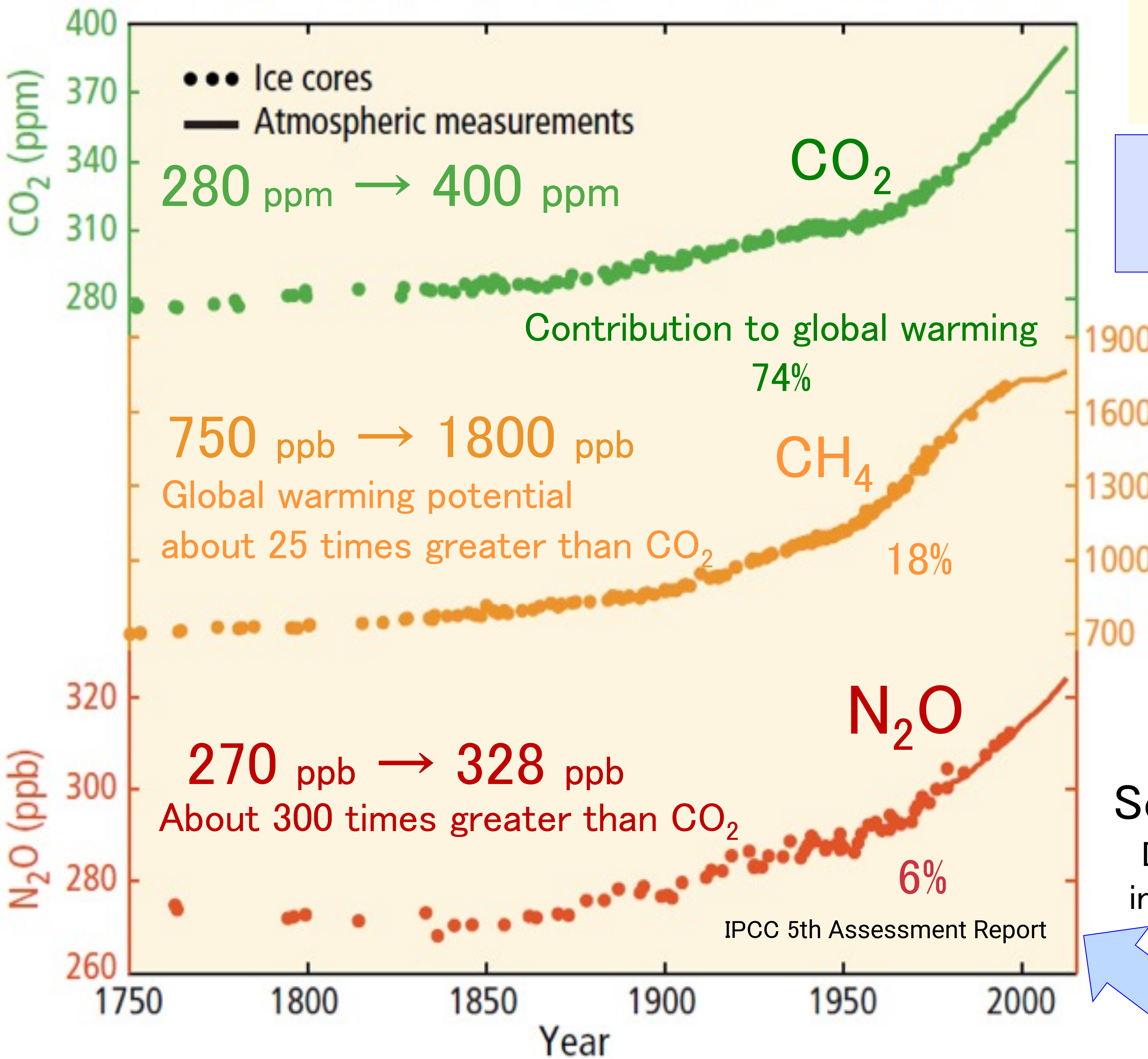
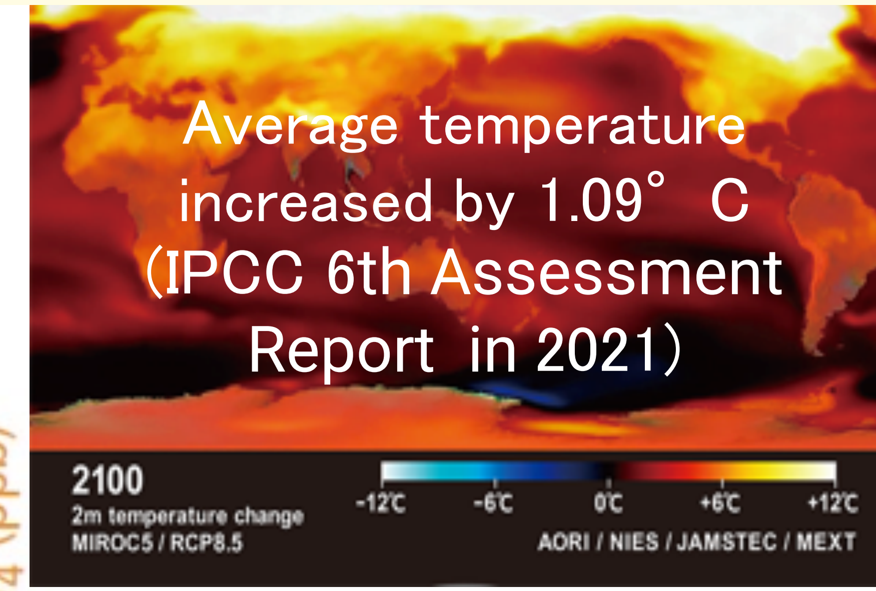
Implementing organizations : Tohoku University, The University of Tokyo
National Agriculture and Food Research Organization (NARO)

Globally averaged greenhouse gas concentrations



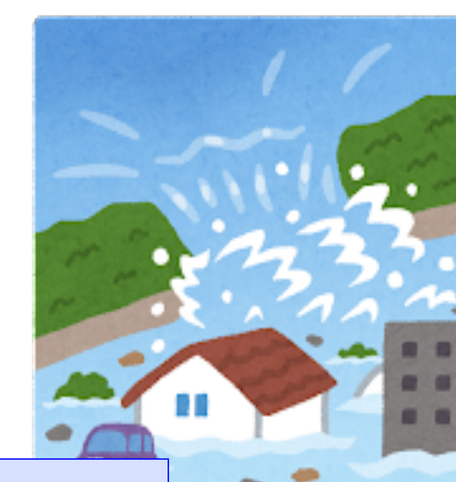
Global warming due to anthropogenic GHG emissions



Increased risk of climate change

Severe disaster

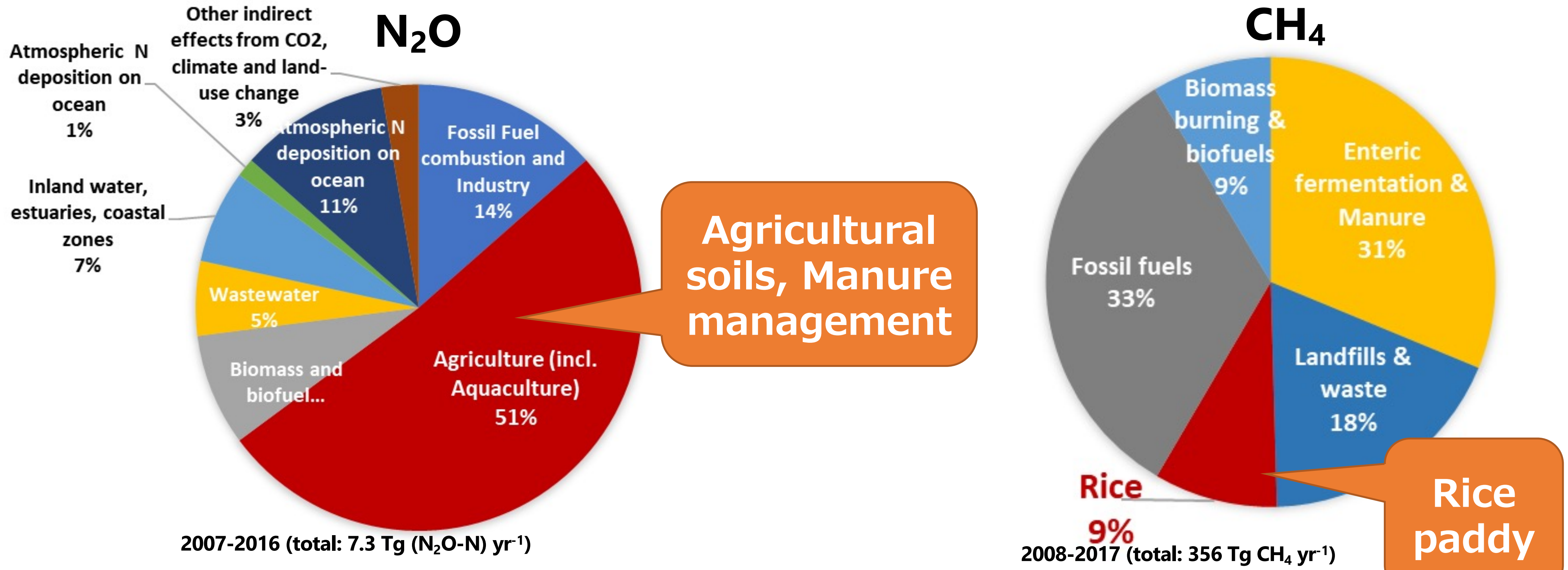
Destruction of the infrastructure of life



Reduction of greenhouse gases other than CO_2 is essential to limit the rise in global temperatures to 1.5 degrees Celsius above pre-industrial levels. (Paris Agreement, COP26)

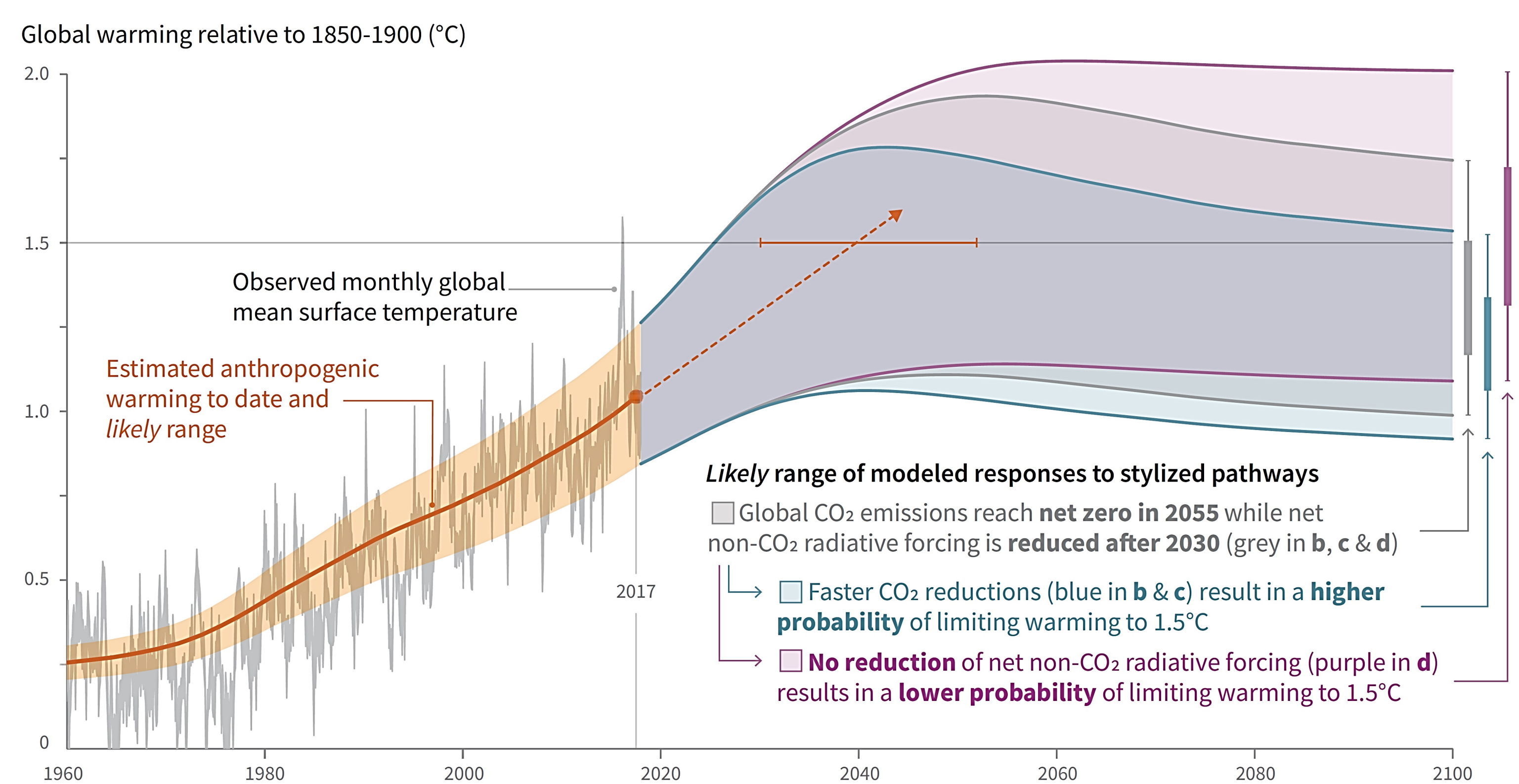
How can we reduce anthropogenic emissions of CO_2, CH_4, and N_2O?

Agriculture: Major Anthropogenic Source of N_2O & CH_4



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

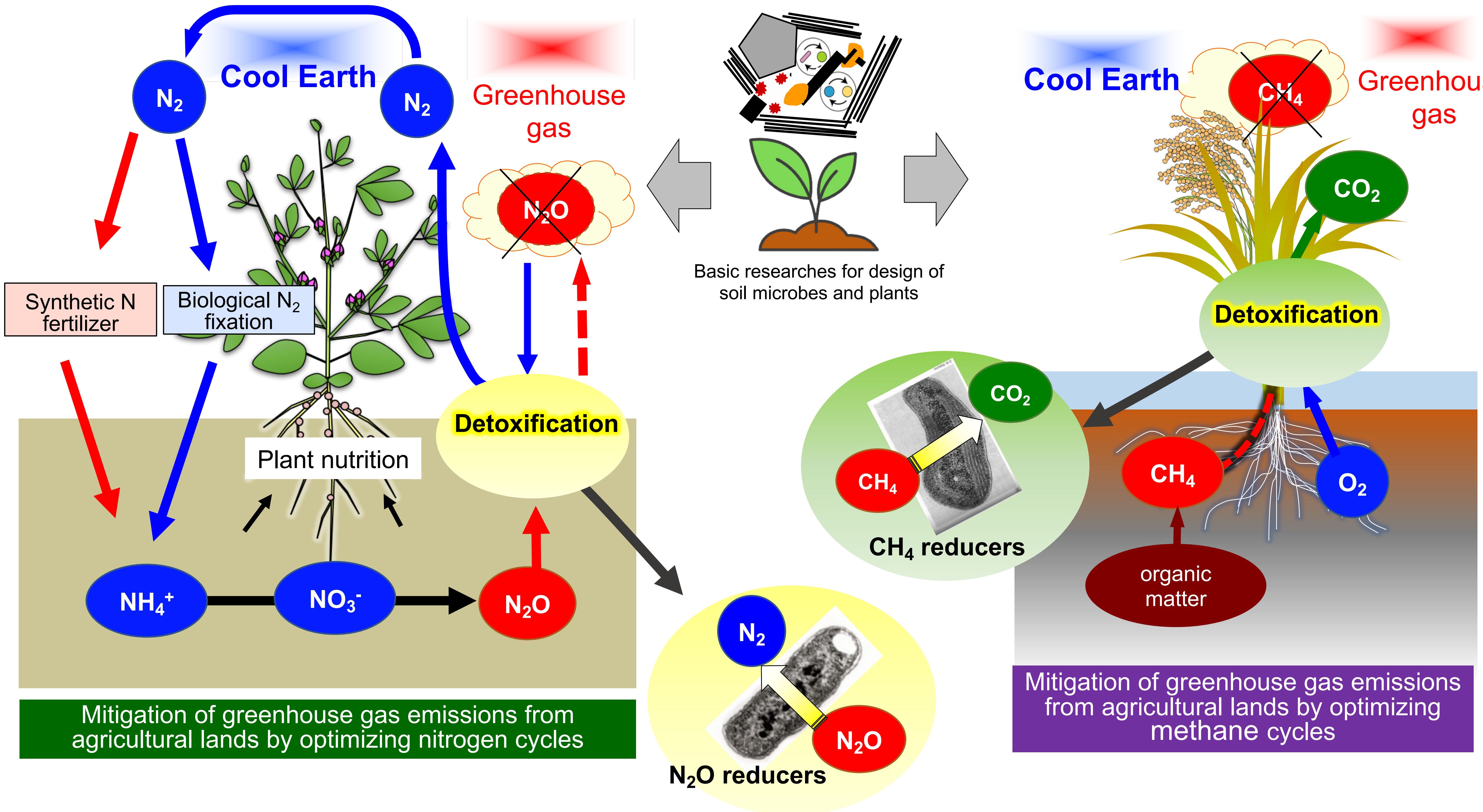
In addition to CO_2 reduction, the reduction of N_2O and CH_4 is needed, to limit global warming to 1.5 °C



(IPCC SR1.5℃, 2018)

Cool Earth via dSOIL

By 2050, 80% mitigation of N_2O and CH_4 from agricultural soils by soil microbes with crops and soil structures.



By microbial diversity of the natural world and all available knowledges and technologies, we aim to reduce anthropogenic GHG emissions and achieve a sustainable nitrogen and carbon cycle.

https://dsoil.jp

Minamisawa MS project themes

Soil structure

N_2O Recycling

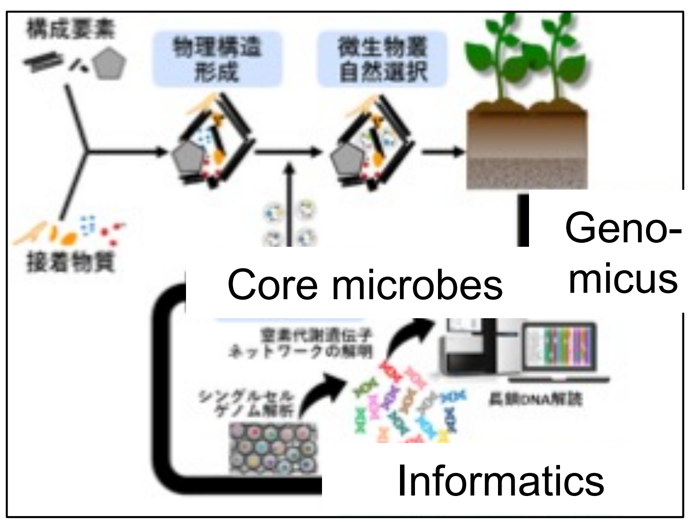
DREAM

*Designing of Reinforced and Effective Agricultural Material

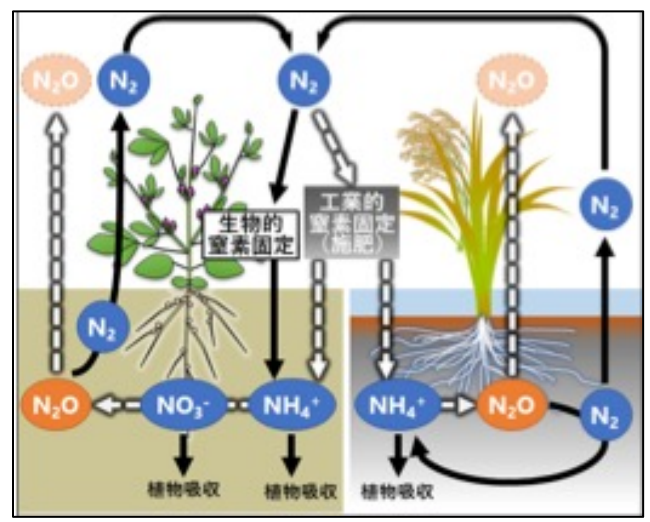
CH_4 Recycling

Assessment & Modeling

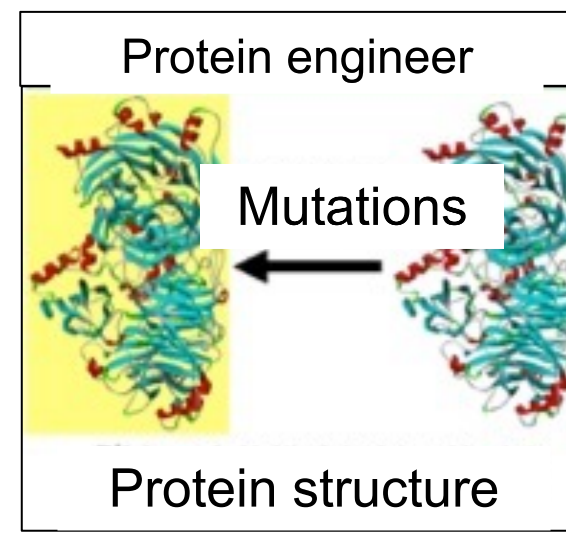
Ⅰ. Soil structure (7 units)



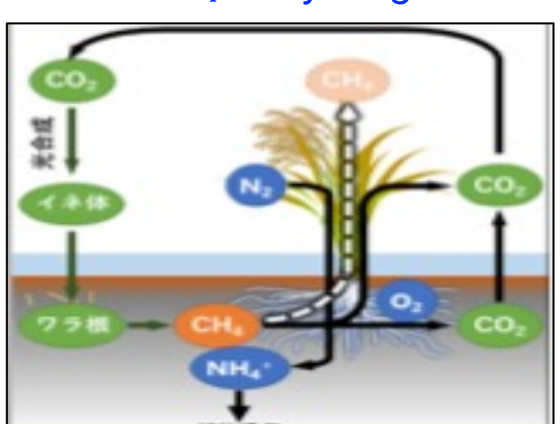
Ⅱ. N_2O Recycling (12 units)



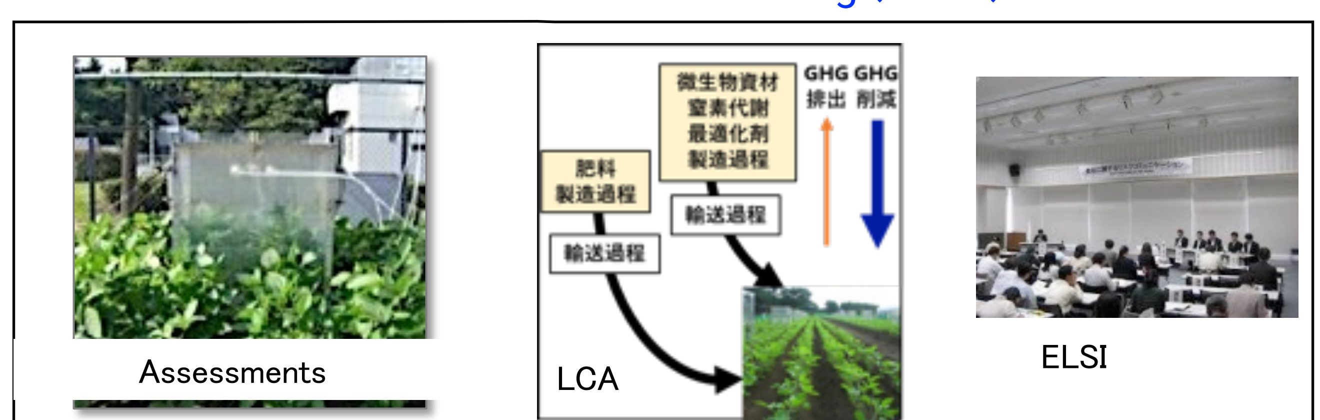
Ⅲ. DREAM (3 units)



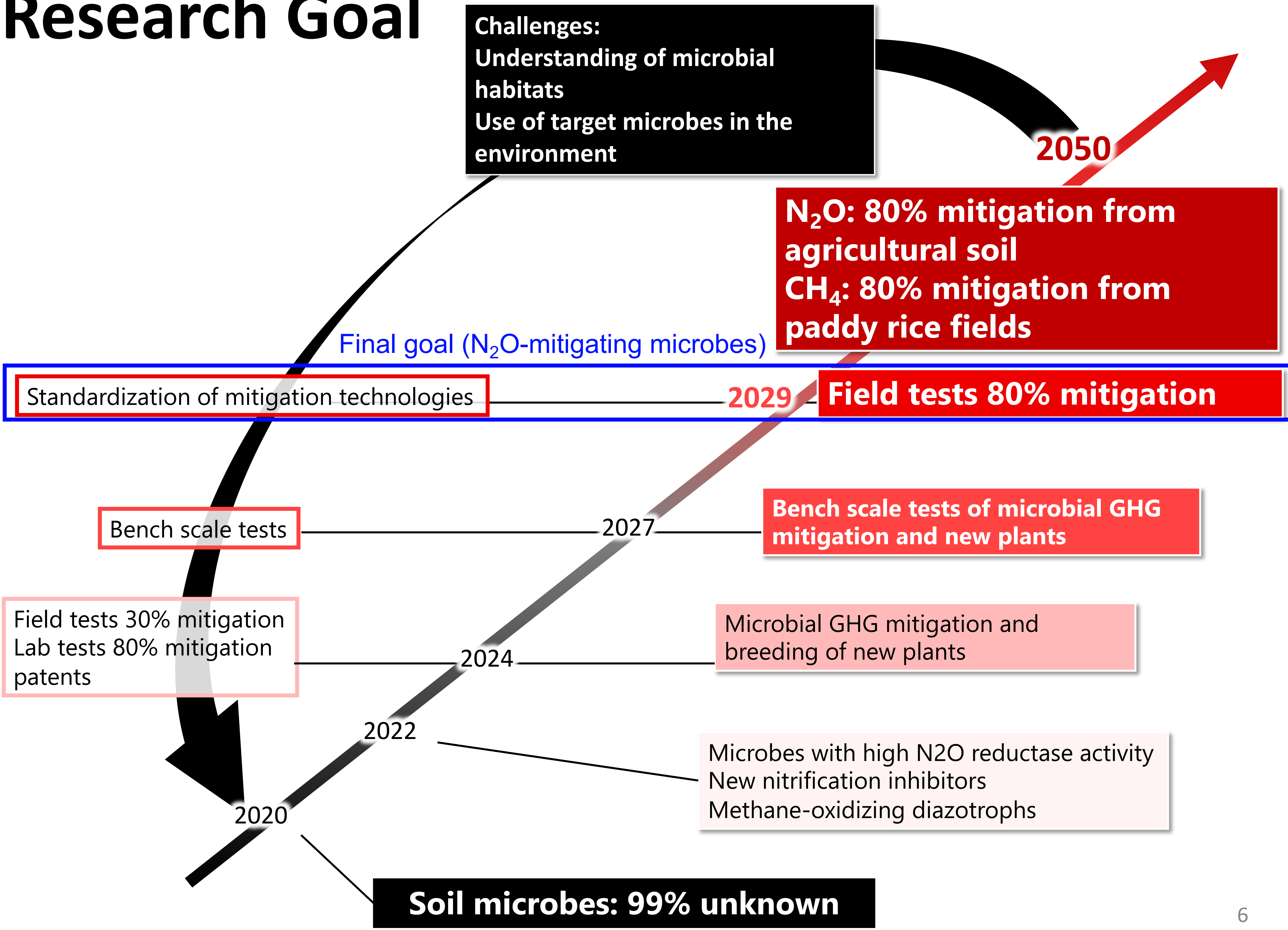
Ⅳ. CH_4 Recycling (3 units)



Ⅴ. Assessment & Modeling (6 units)



Research Goal

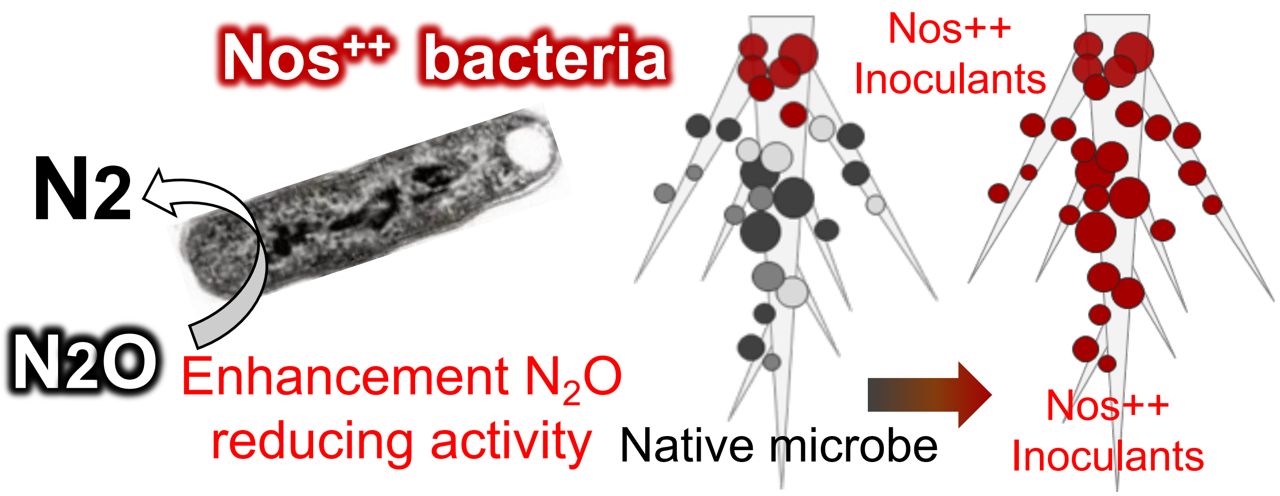


Examples of social implementation

2020 → 2024 → 2029

N_2O detoxifying rhizobia

Exploration and generation of Nos++ strains with enhanced N_2O reduction activity



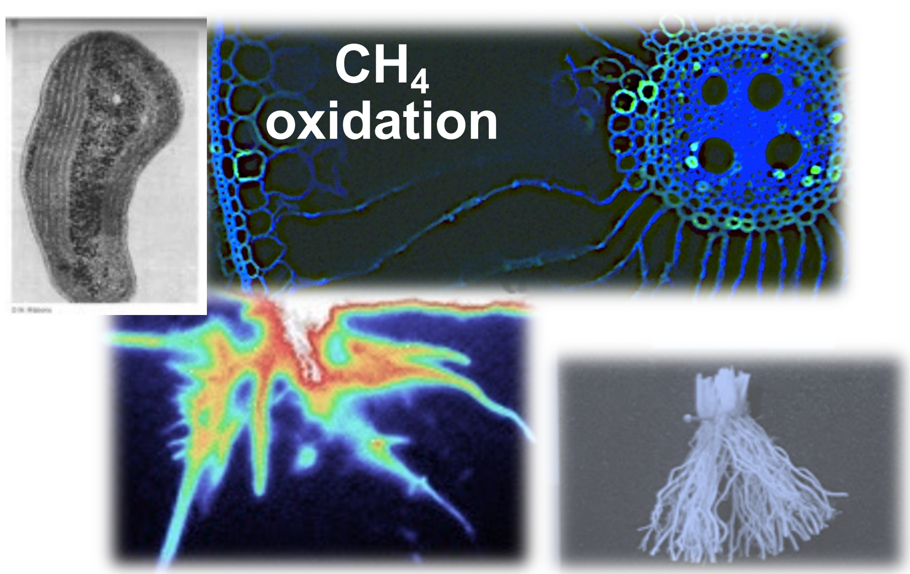
Breeding of host plant

Commercialization as a set of microorganism + seeds + carrier

Social acceptance of microbial inoculation for Cool Erath

Rice paddy CH_4 reduction

Development of new technologies for low-methane rice



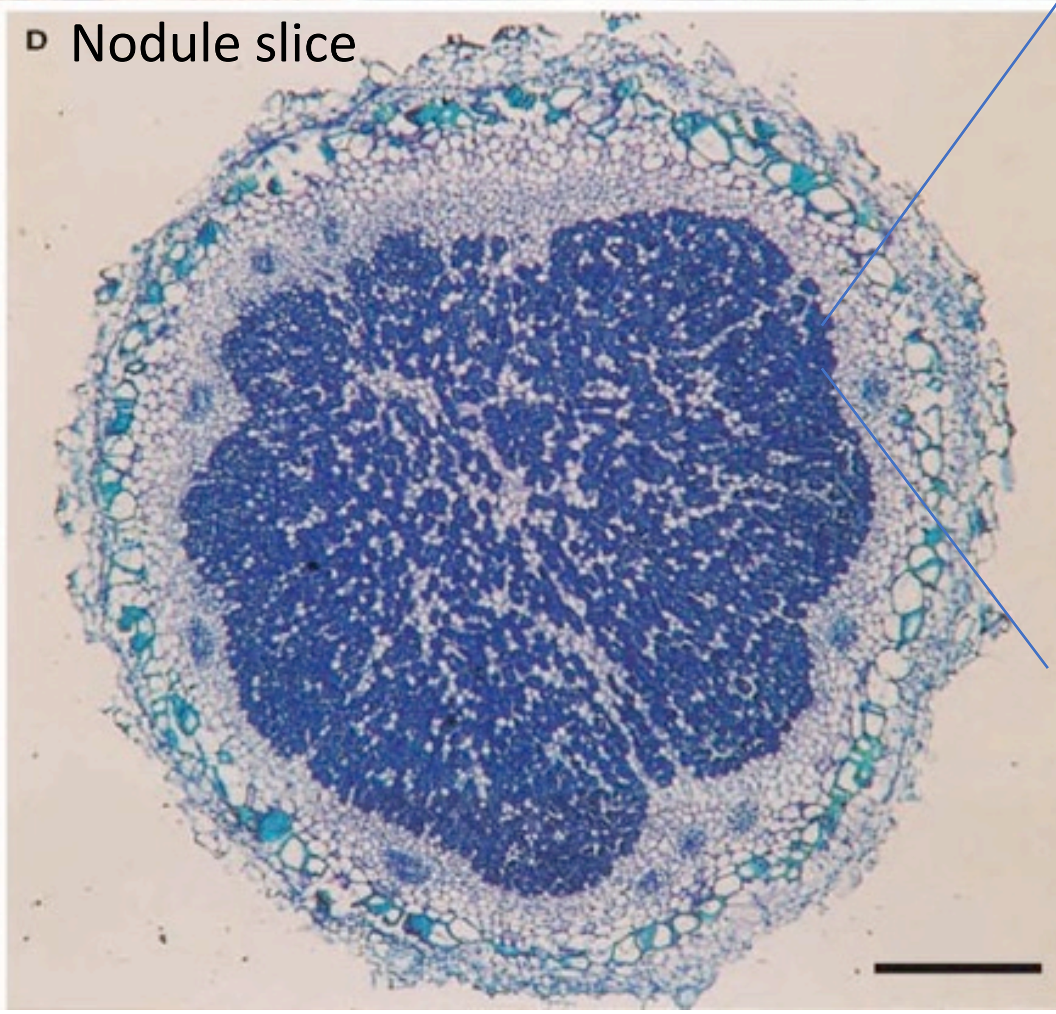
Reduce Methane Emissions from Major Products + (Diazotrophic methanotrophs)

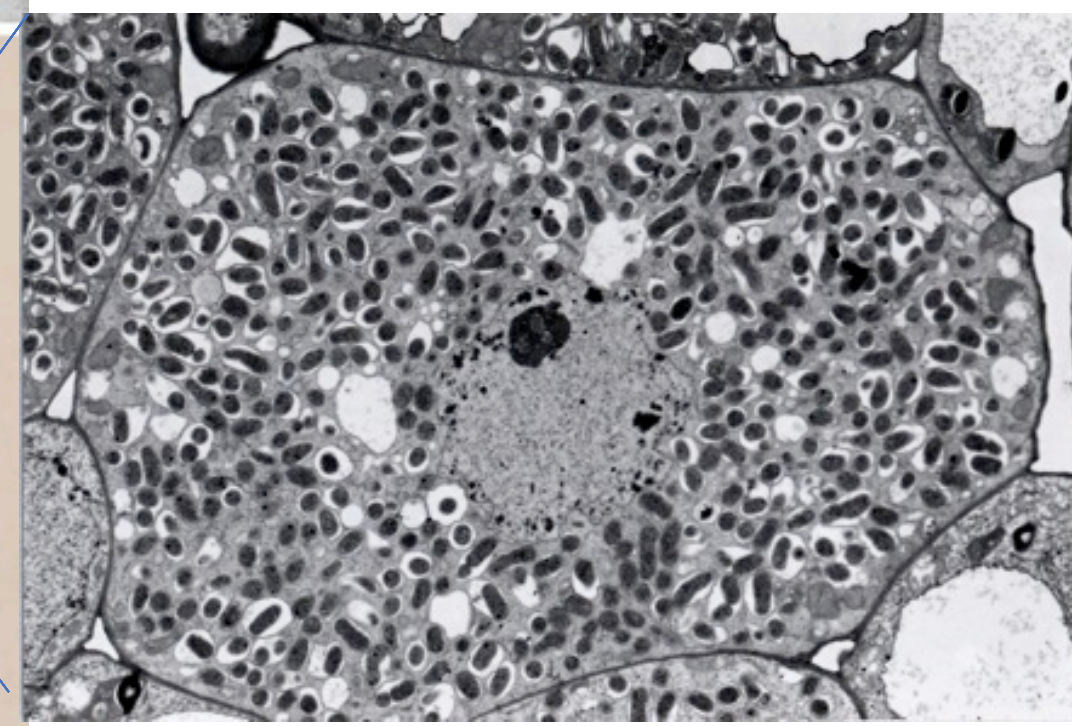
Rhizobial symbiosis

Soil bacteria that form nodules on legume crop roots and perform nitrogen fixation

$$N_2 + 8e + 8H^+ \rightarrow 2NH_3 + H_2$$

Nitrogen gas (N_2) to ammonia



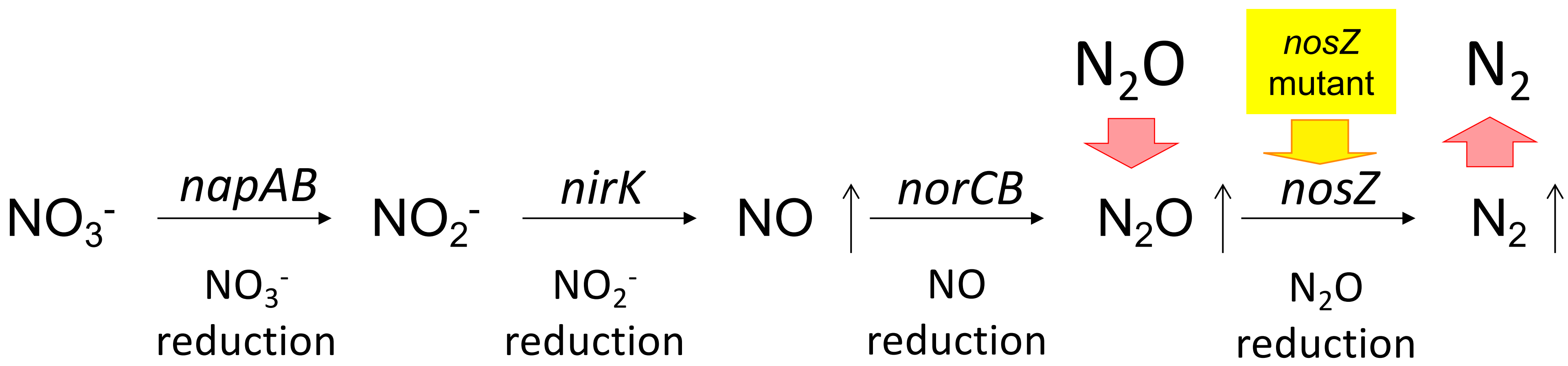


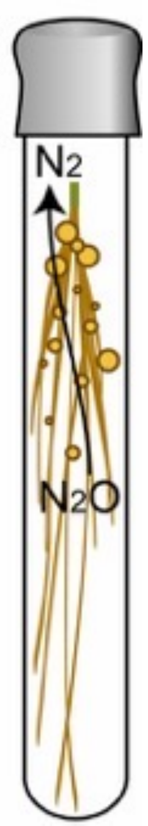
A Soybean plant**, B** Electron micrograph of *Bradyrhizobium* cell, **C** Soybean root with nodules, **D** Micrograph of nodule slice. Blue cells are plant cells infected with *Bradyrhizobium*. Bars : **B** 0.5μm ; **D** 0.5mm.

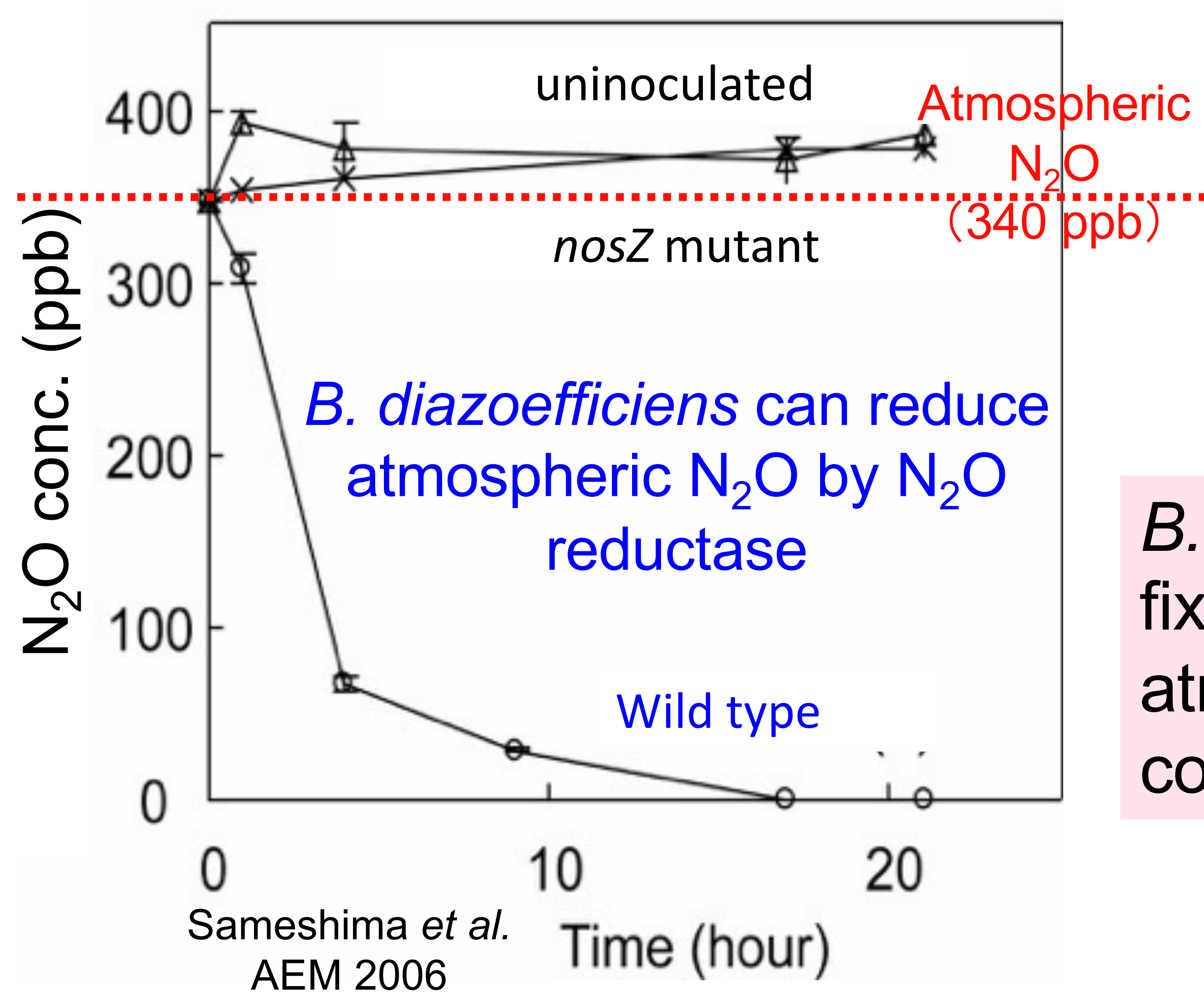
(Photographs by Prof. Kiwamu Minamisawa)

Bradyrhizobium diazoefficiens reduces greenhouse gas N_2O

Denitrification pathway of *Bradyrhizobium diazoefficiens*



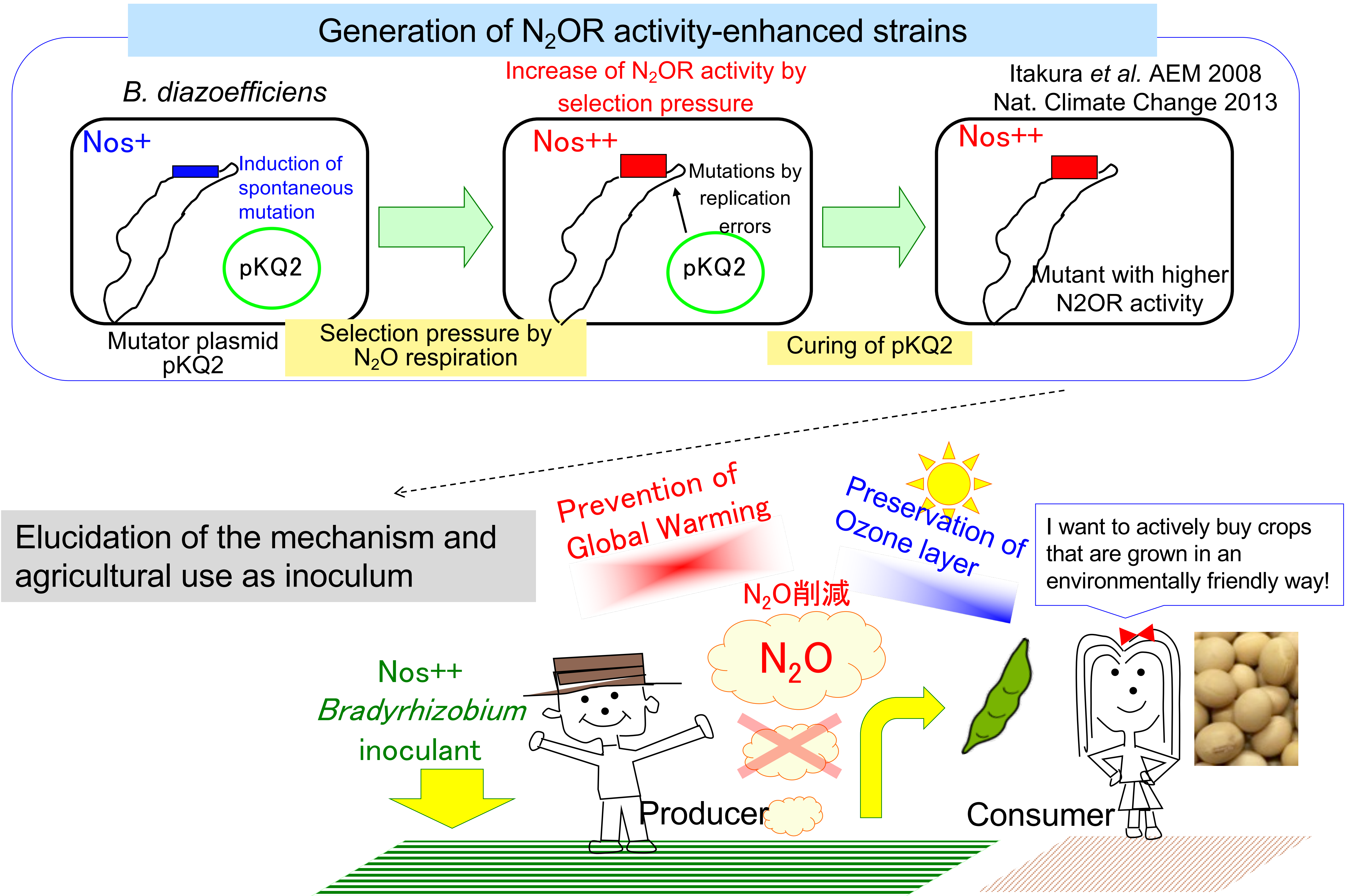




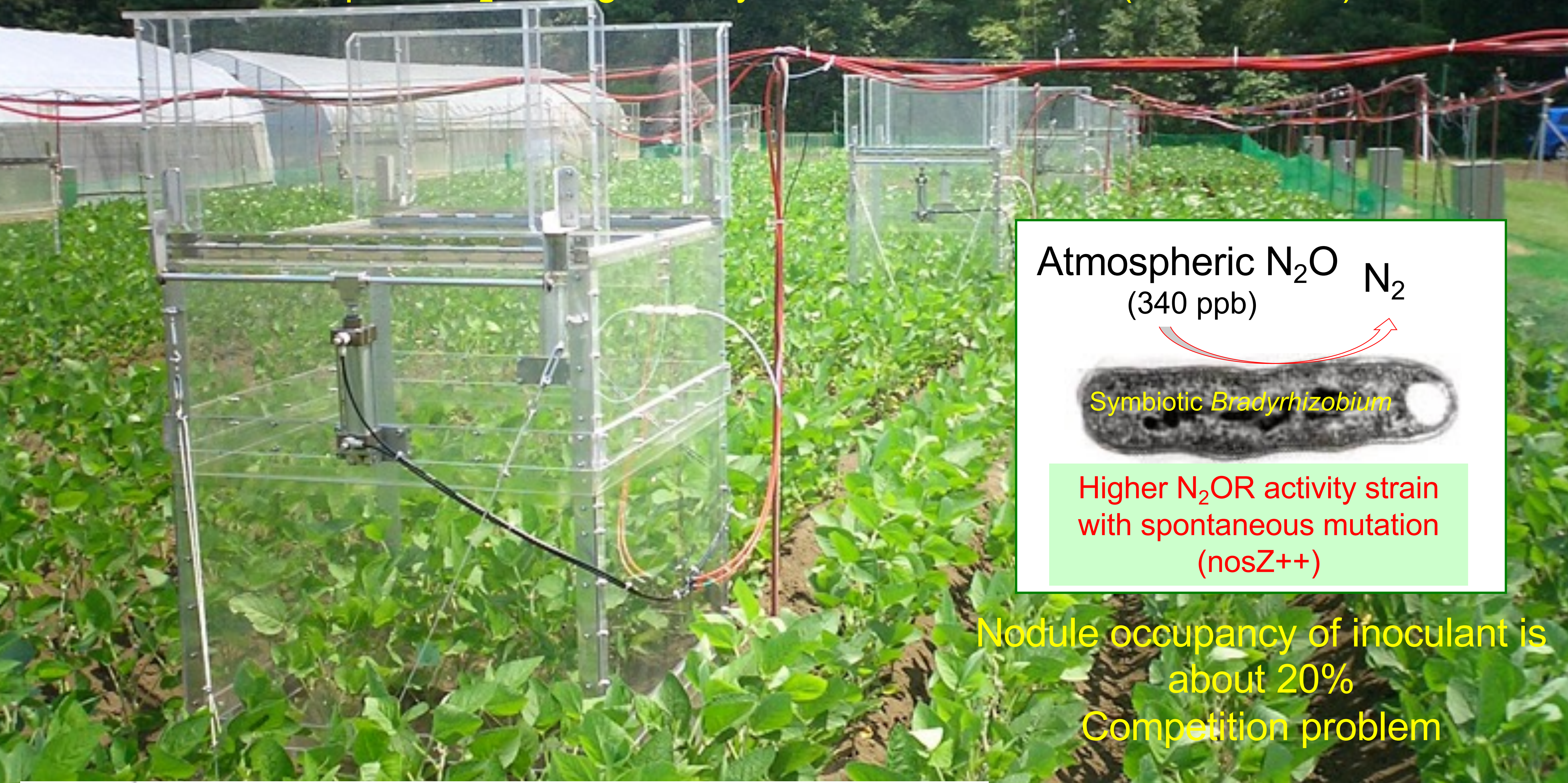
Sameshima *et al.* AEM 2006

B. diazoeffciens not only fix nitrogen but uptake atmospheric low concentration N_2O.

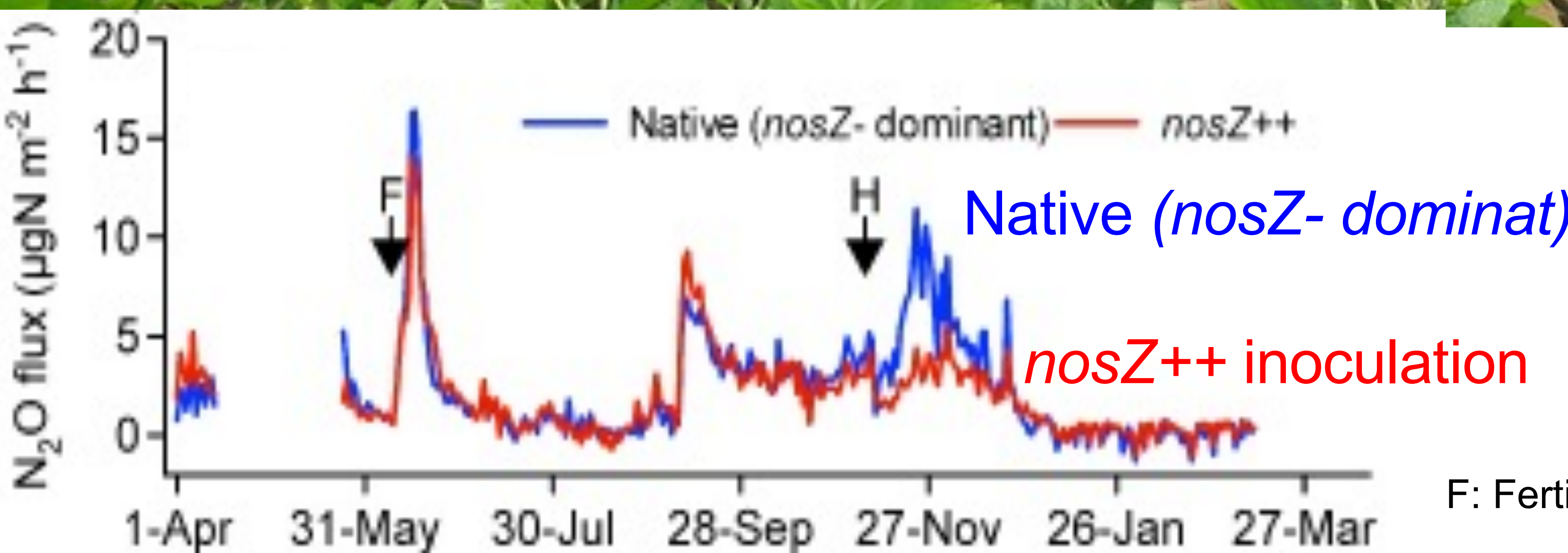
Generation of N_2OR activity-enhanced strains by mutations and genome editing



An example of N_2O mitigation by rhizobial inoculation (NARO Field)



Nodule occupancy of inoculant is about 20%
Competition problem



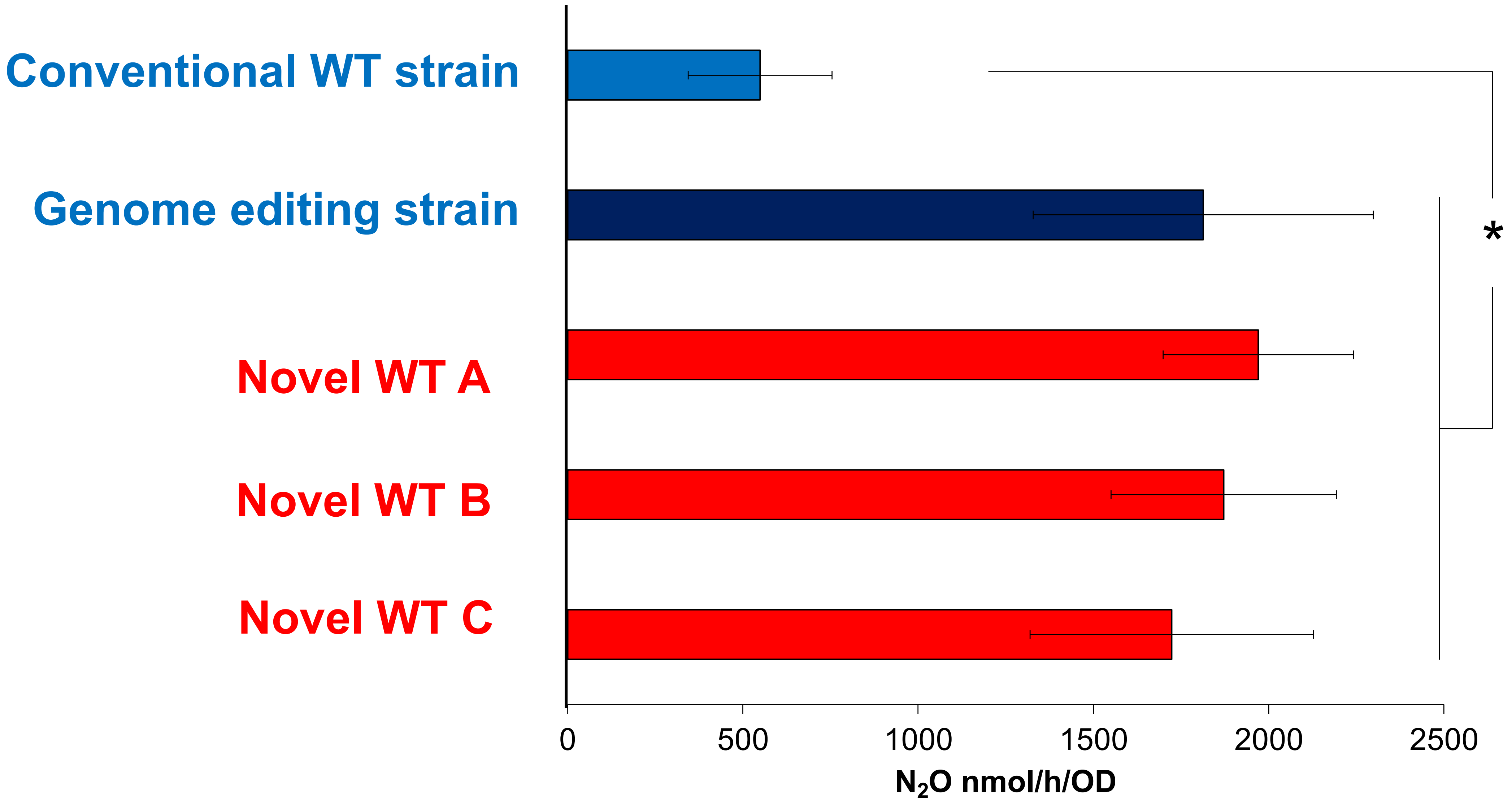
Pioneering research

Itakura *et al.* Nature Climate Change, 2013

F: Fertilization 、H: Harvest

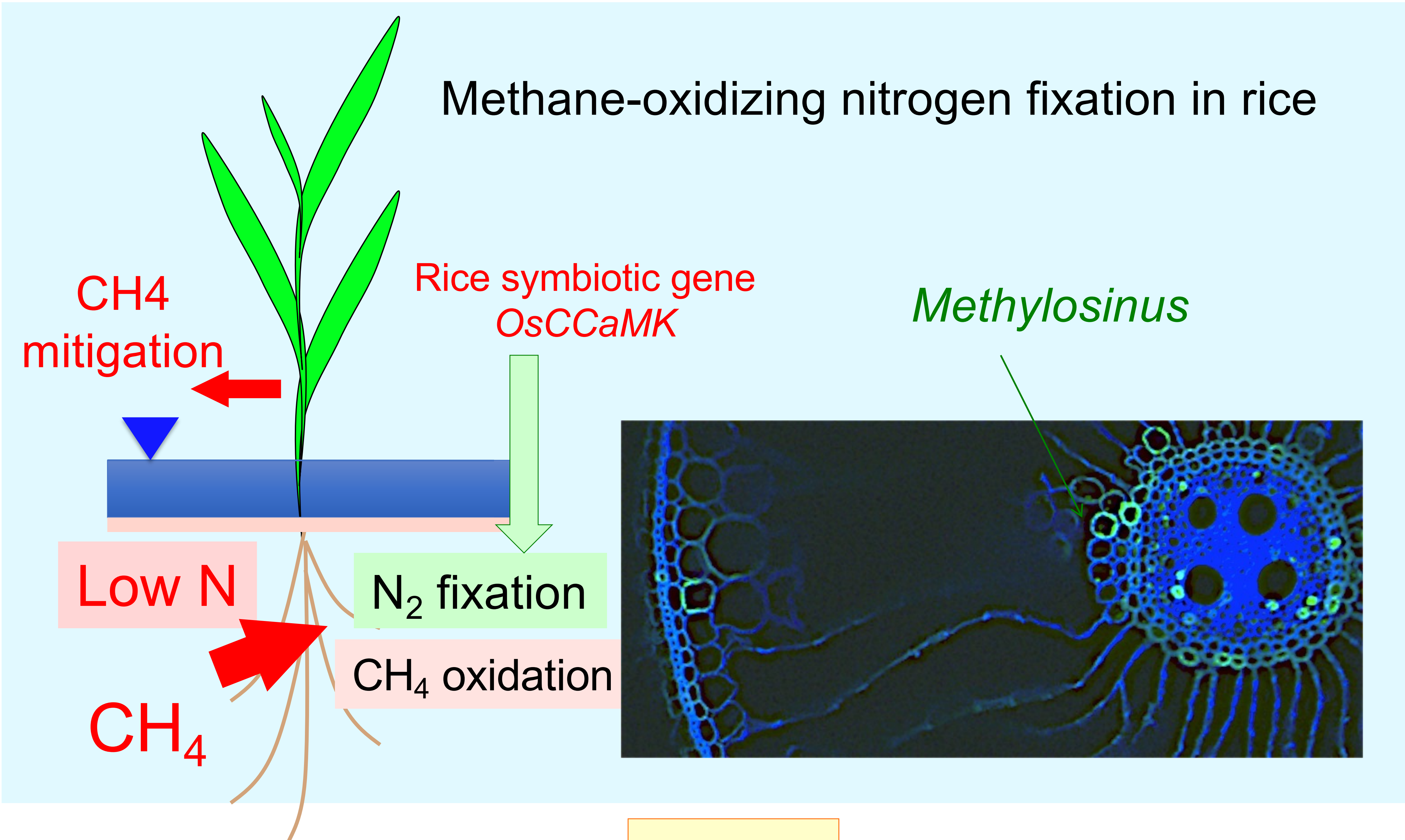
Recent result

We found novel wild type Nos++ strains.



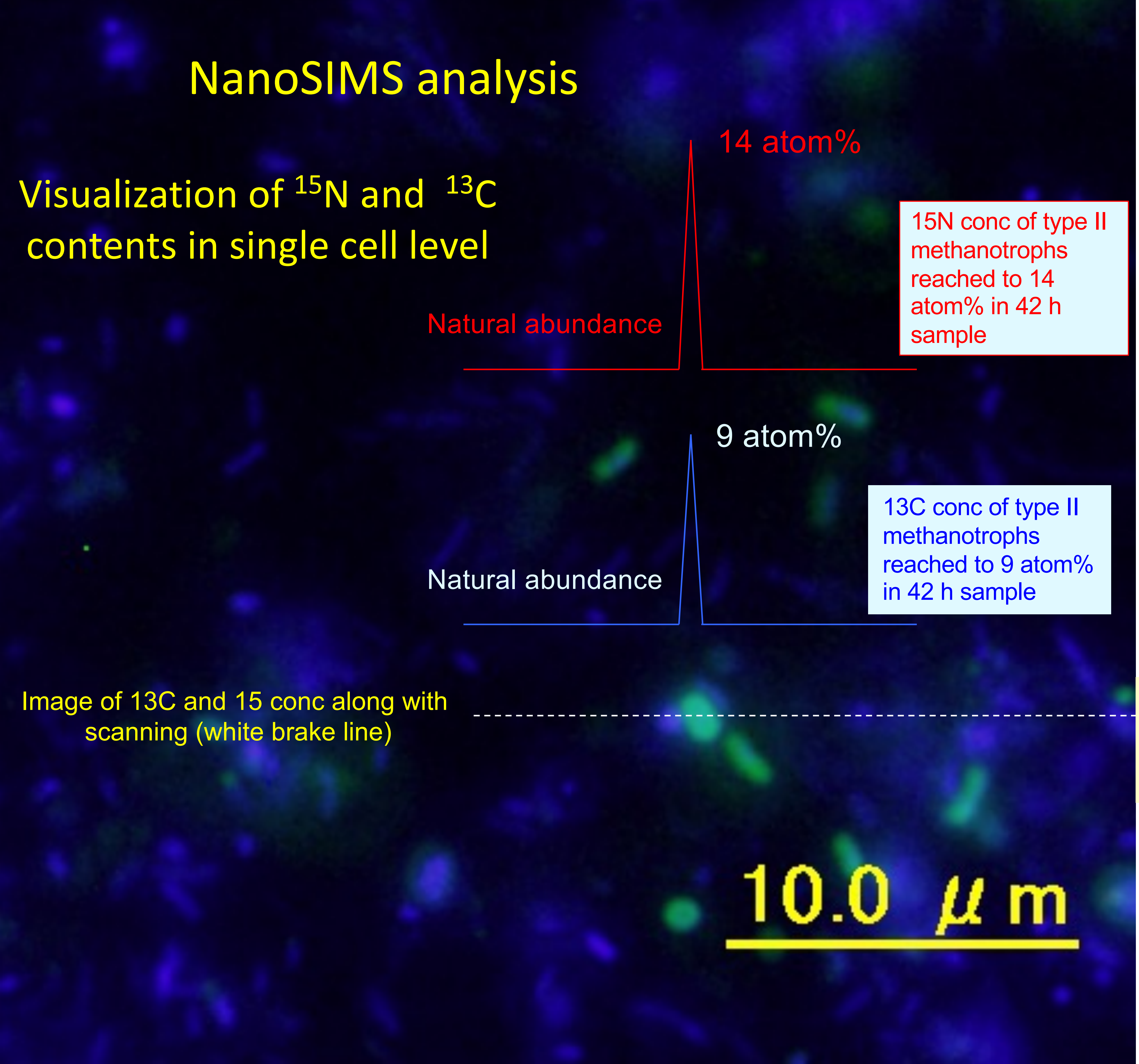
N_2OR activity in free-living condition

These effective strains are shared with MS members to study their usefulness.



IV-2-a Mechanism for colonization in rice roots
IV-2-b Isolation of microbes with the higher activities

Recent result

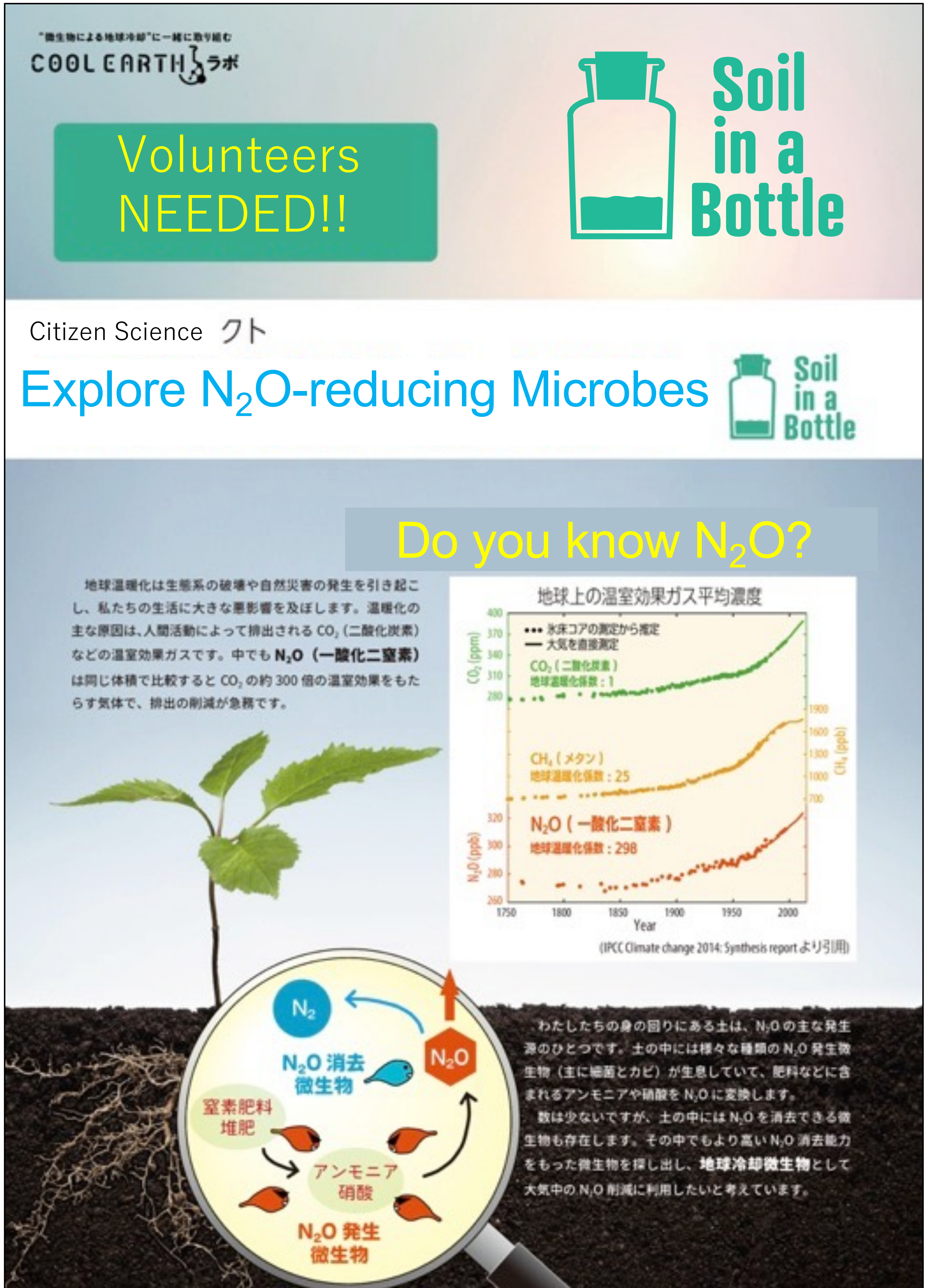


Images of FISH (green) and15N/13C isotope ratio for the symbiotic microbes in rice root at 42-h incubation, where root systems of field-grown rice plants were incubated with a gas phase containing 13CH4 (6% [v/v], 99 atom% of 13C) and 15N2 (35% [v/v], 99.4 atom% of 15N) and O2 (12% [v/v]) in Ar balance for 42-h.

We will enhance these activity by rice breeding and selected methnotrophs.

Public participation project (Citizen Science)

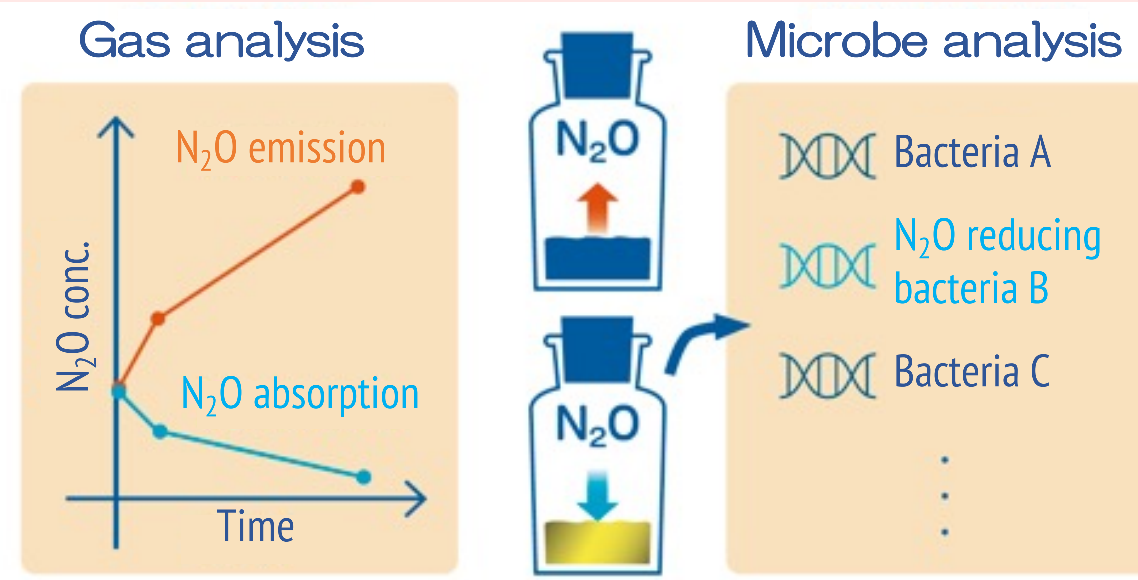
https://dsoil.jp/soil-in-a-bottle/



Citizen science project
"Explore N_2O-reducing Microbes"

Interactive communication between citizens and scientists (ELSI)

Search for N_2O reducing soils and microbes



Students at Miyagi First senior high school

MOONSHOT

RESEARCH & DEVELOPMENT PROGRAM