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Climate change mitigation potential of Japanese agricultural soils estimated by country-scale simulation of soil carbon stock change and CH_4 and N_2O emissions

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Outline

- **Introduction** – Research questions
- **Methods** – Modeling GHGs at country scale
  - CO_2 (Soil C): RothC (Shirato et al.)
  - CH_4: DNDC-rice (Fumoto et al.)
  - N_2O: Developing empirical model (this study)
  - Mitigation scenarios
- **Results**
  - Total emission of GHGs (1980-2013)
  - Mitigation potential and trade-off (2020-2050)

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Introduction | Methods | Results | Conclusions

Research Questions

To assess the climate mitigation potential of Japanese agricultural soils through improved management practices, we have to answer two questions:

1. Historical trends in total GHG emissions (1980-2013)
2. Simulate future mitigation potential by comparing BAU and mitigation scenarios (2020-2050)

- at country scale
- all land-use categories (paddy, upland, orchard and grassland)

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Introduction | Methods | Results | Conclusions

Evaluating total GWP at country scale by models

e.g. Mitigation option: “Increase C inputs to soils”

Total GWP(Global warming potential)

- Evaluating total GHGs (GWP) considering “Trade- off”.
- Country scale evaluation with models (IPCC tier 3) for each gas

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Introduction | **Methods** | Results | Conclusions

Roth-C model for simulating
Soil carbon stock change

Soil C
(CO_2)

Led by Dr. Y. Shirato

- Shirato et al. 2004
- Shirato & Yokozawa 2005
- Yagasaki & Shirato 2014a, b

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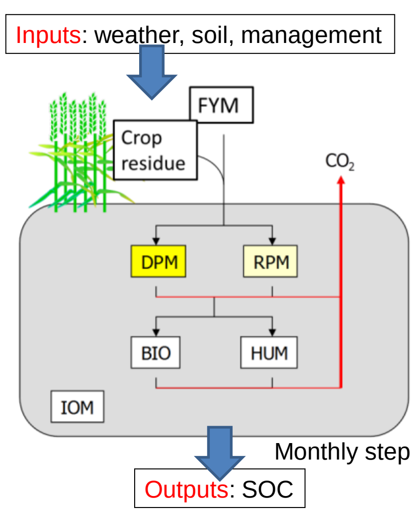
Introduction | **Methods** | Results | Conclusions

Soil C: Rothamsted Carbon (RothC) model



- Japanese version
- Modified RothC model for paddy soils and for Andosols (volcanic ash-derived soils)

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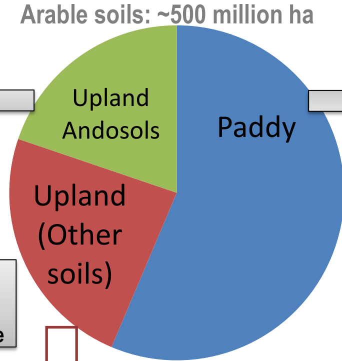
Soil C: National-scale simulation using 3 versions

~50% of upland soils:

Arable soils: ~500 million ha



~50% of arable soils:

Volcanic ash derived
➔Stable HUM + Al_{active}

Anaerobic condition
➔Slow decomposition

Modified model
(Shirato et al., 2004)

Original RothC
(Shirato & Taniyama, 2003)

Modified model
(Shirato & Yokozawa, 2005)

DNDC-rice model for simulating
CH_4 Emission from rice paddy

CH_4

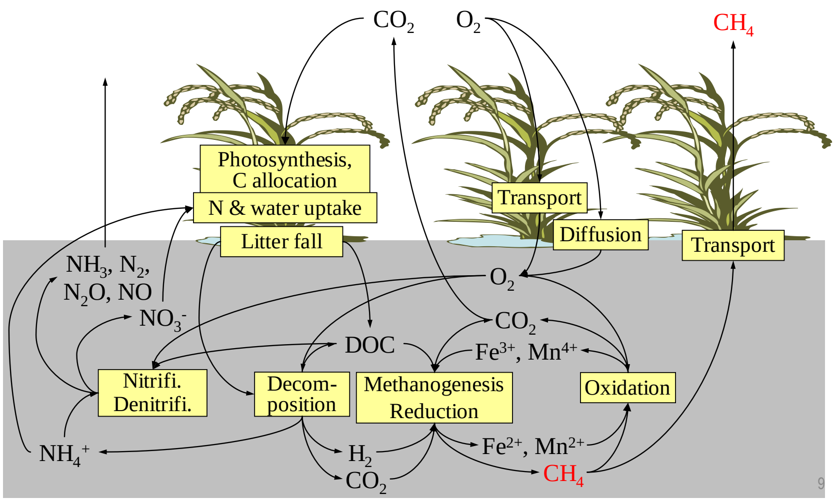
**Led by Dr. T. Fumoto
and N. Katayanagi**

- Fumoto et al. 2008, 2010, 2013
- Katayanagi et al. 2016, 2017

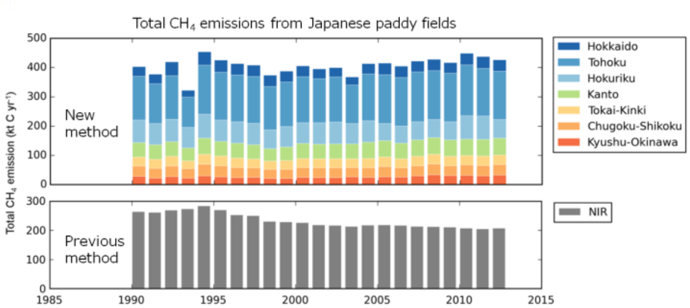
CH_4: DNDC-Rice model

Modified version of DNDC for paddy rice field

(Fumoto et al., 2008, 2010, 2013)



New EFs generation by DNDC-rice for estimating CH_4 emission at national scale



Temporal variability of the annual total CH_4 emission from Japanese paddy fields from 1990 to 2012 calculated by (upper) using EFs generated by DNDC-Rice model and (lower) the previous National Inventory Report

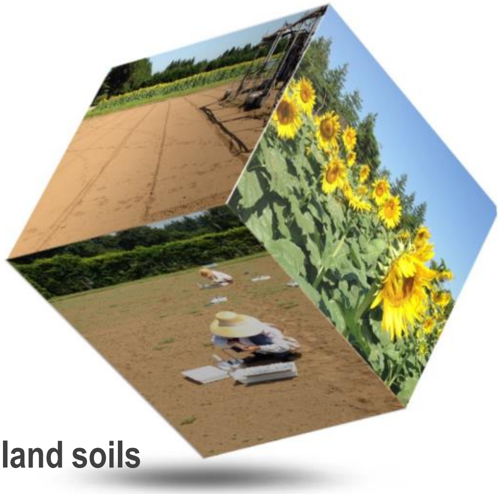
(Katayanagi et al., 2017)

Introduction | **Methods** | Results | Conclusions

Empirical model for estimating
Direct N_2O Emission from soils

N_2O

This study



- ✓ Andosols: ~50% of upland soils
- ✓ High SOC
- ✓ Stable humus with active Al
- ✓ Low N_2O emission

Difficulty on developing N_2O process model

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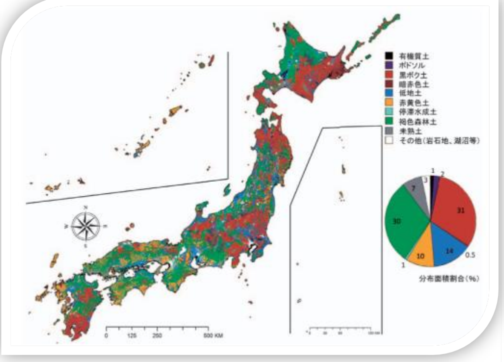
Introduction | **Method** | Results | Conclusions | N_2O

Research mission:
Estimate N_2O emission at national scale using model



Soil types and distribution in Japan
(Obara et al., 2016)

Concept

- ✓ Simple model that match the resolution of activity data (N application and managements)
- ✓ Simple model but could catch the effluence of climate and the difference of soil type

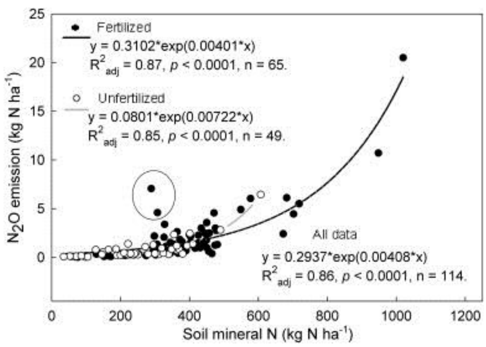
Introduction | **Method** | Results | Conclusions | N_2O

N_2O empirical model (Mu et al. 2009):

Linking N_2O emission to soil mineral N as estimated by CO_2 emission and soil C/N ratio

Mineralized N from OM

$$\text{Cumulative}N_2O\ \text{emission} = A \exp [B^*(E_{CO2}/S_{CN}+Fn)]$$



Decomposed-CO_2: Changed with climate

C:N of organic matter

Chemical fertilizer N

RothC

Upland soils, N_2O&CO_2 datasets

Mu et al. (2009) soil Bio. Bichem. 41: 2593-2597

96 data from USA (4 sites), German (4 sites) and Canada (1 site); 14 data from Japan (2 sites); 4 data from China (1 site)

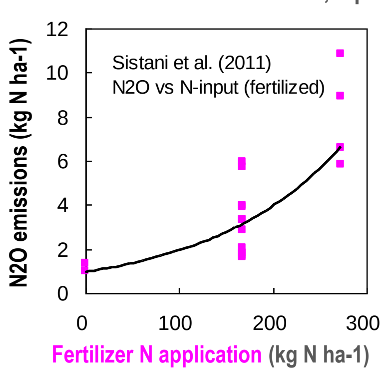
Introduction | **Method** | Results | Conclusions | N_2O

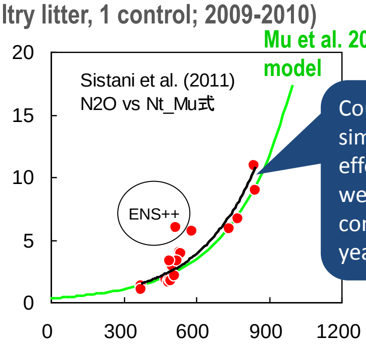
Validation of Mu et al. (2009) at a plot scale - Case in different N treatment-

Validation dataset: Sistani et al (2011) JEQ 40: 1797-1805

Upland Soil: Crider silt loam (Bowling Green, USA)

Crop/Treatment: No-till corn; Different N fertilizers (6 chemical fertilizers, 2 poultry litter, 1 control; 2009-2010)



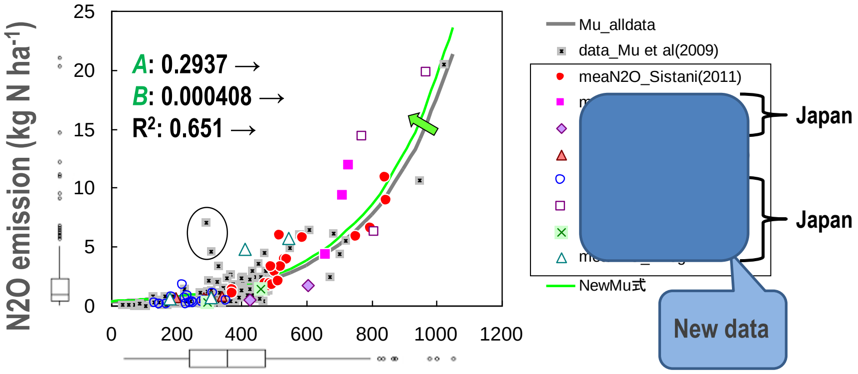


Could simulate the effects of weather condition year-by-year

Use data with author permission

Validation of Mu et al. (2009) using more datasets from different sites

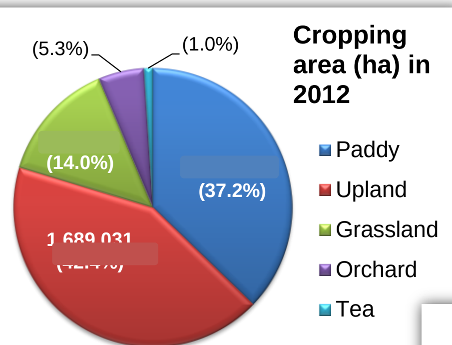
$$\text{Cumulative}N_2O\text{ emission} = A \exp[B^*(E_{CO2}/S_{CN}+Fn)]$$



Soil mineral N (kg N ha-1) as (E_{CO2}/S_{CN}+Fn)

RothC

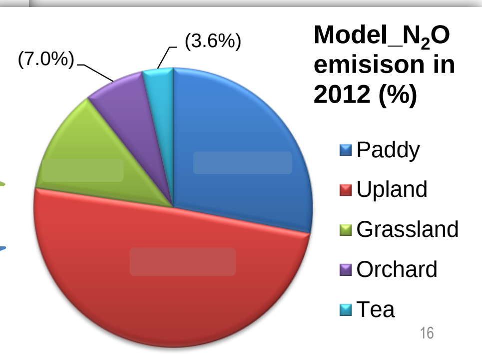
Activity data



N_2O: Contribution of land-use categories (2012)

Upland contributed 49% ＞Paddy＞Grassland ≒(Orchard+Tea)

Tea emitted 3% of total with 1% planting area



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Future projection

2 climate change scenarios:
1GCM × 2 emission scenarios
- **MIROC5, rcp26**
- **MIROC5, rcp85**

Rcp: Representative Concentration Pathways

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4 management scenarios:
- **BAU**
- **Mitigation -1, 2, 3**

Scenario	Soil C input	Paddy water management	N fertilizer
BAU	conventional	conventional	conventional
Mitigation1	+10%	conventional	conventional
Mitigation2	+10%	Extend MSD	conventional
Mitigation3	+10%	Extend MSD	-10%

MSD: Mid-season drainage

Summary: total mitigation potential

Scenario	C input	Paddy water management	N fertilizer	Mitigation potential vs. BAU (ktCO$_2$-eq./yr : minus: mitigation)				
				CO_2 (Soil C)	CH_4	N_2O	CO_2 (Fossil fuel	Total GWP
BAU	conventional	conventional	conventional					
Mitigation1	+10%	conventional	conventional					
Mitigation2	+10%	Extend MSD	conventional					
Mitigation3	+10%	Extend MSD	-10%					

Average of 2020-2050 (per year)
Average of two climate change scenarios

- +10% C input decrease CO_2 but increase CH_4 and N_2O. Total GWP increase.
- Extending MSD decrease CH_4, and its application in 50% paddy field can offset the above increase in GWP. Total GWP decrease.
- -10% N application decrease N_2O. Total GWP decrease more (**trade-off can be offset**).
- “Mitigation scenario 3” can decrease 5% of total GWP including fossil fuel derived CO_2.

Introduction | Methods | Results | Conclusions | **Application**

Developing "Web tool" for calculating GHGs from Japanese agricultural soils

土壌のCO_2吸収「見える化」サイトの拡充：メニューの追加

Web tool already established

http://soilco2.dc.affrc.go.jp/

Led by Dr. Y. Shirato

Calculator for Greenhouse gases from agricultural soils

- CO_2 (SoilC, fossil fuel)
- CH_4 (paddy rice)
- N_2O

- More mitigation options (coming soon)

Thank you for your attention.

Any question?

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