Nation-scale estimation of methane emission from paddy fields in Japan using a biogeochemistry model

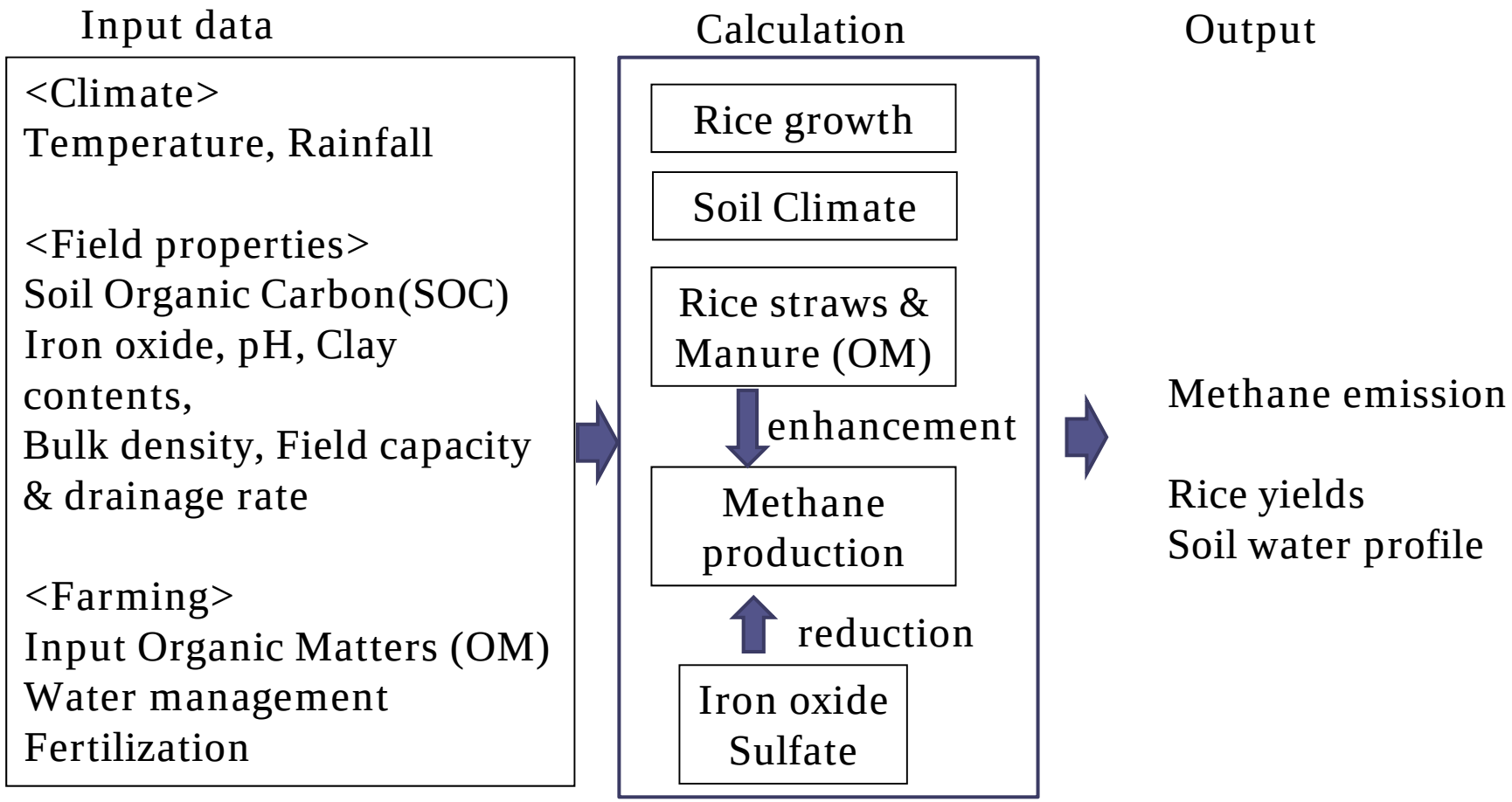
Michiko Hayano
Tamon Fumoto
Kazuyuki Yagi
National Institute for Agro-environmental sciences (NIAES)

Objectives

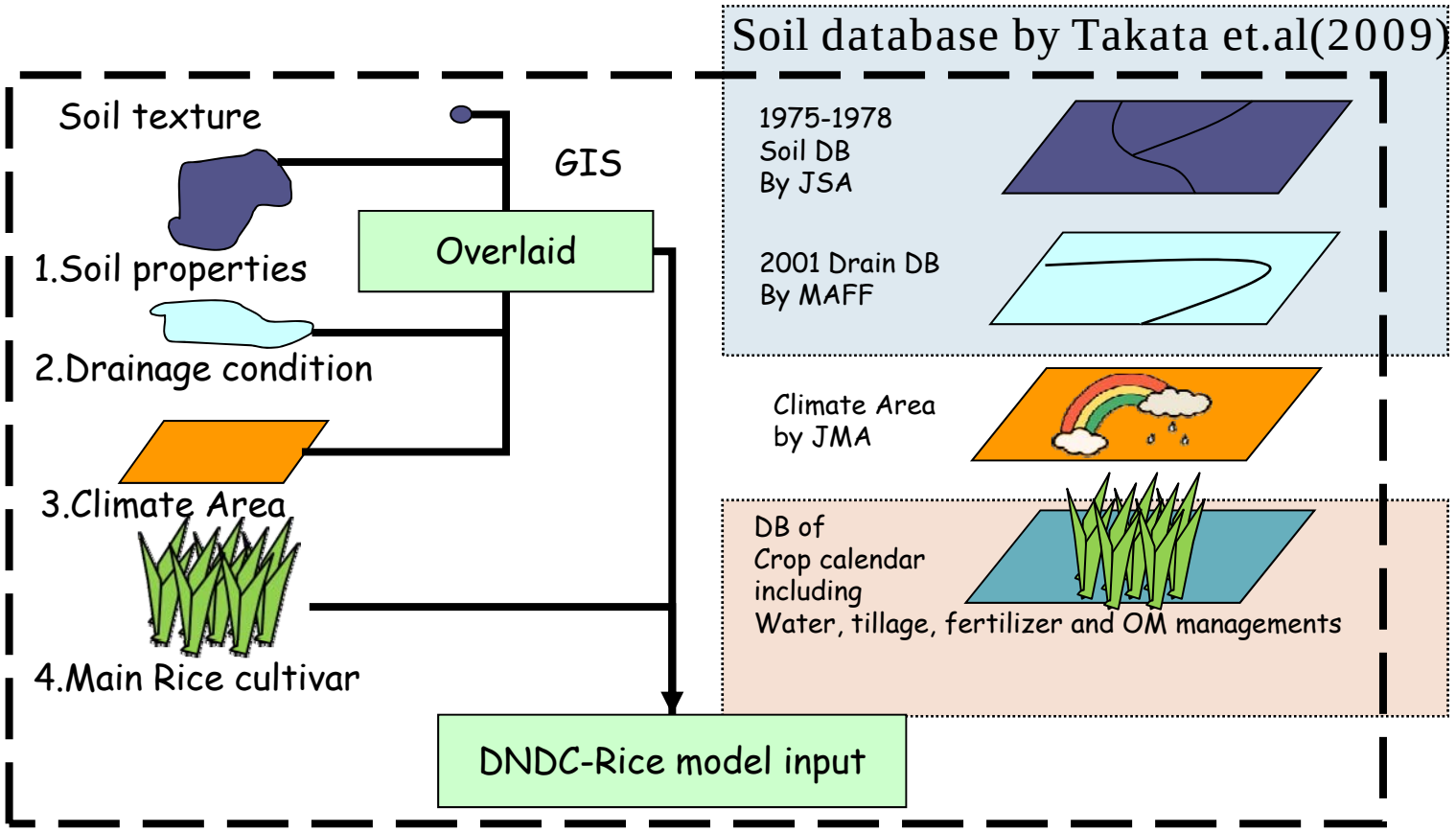
- To estimate methane emission from rice fields at nation-scale, taking into account the spatial variations in drainage condition, soil type, climate, and irrigation and organic matter (OM) managements

DNDC-Rice model

Fumoto et.al.(2008), GCB in detail

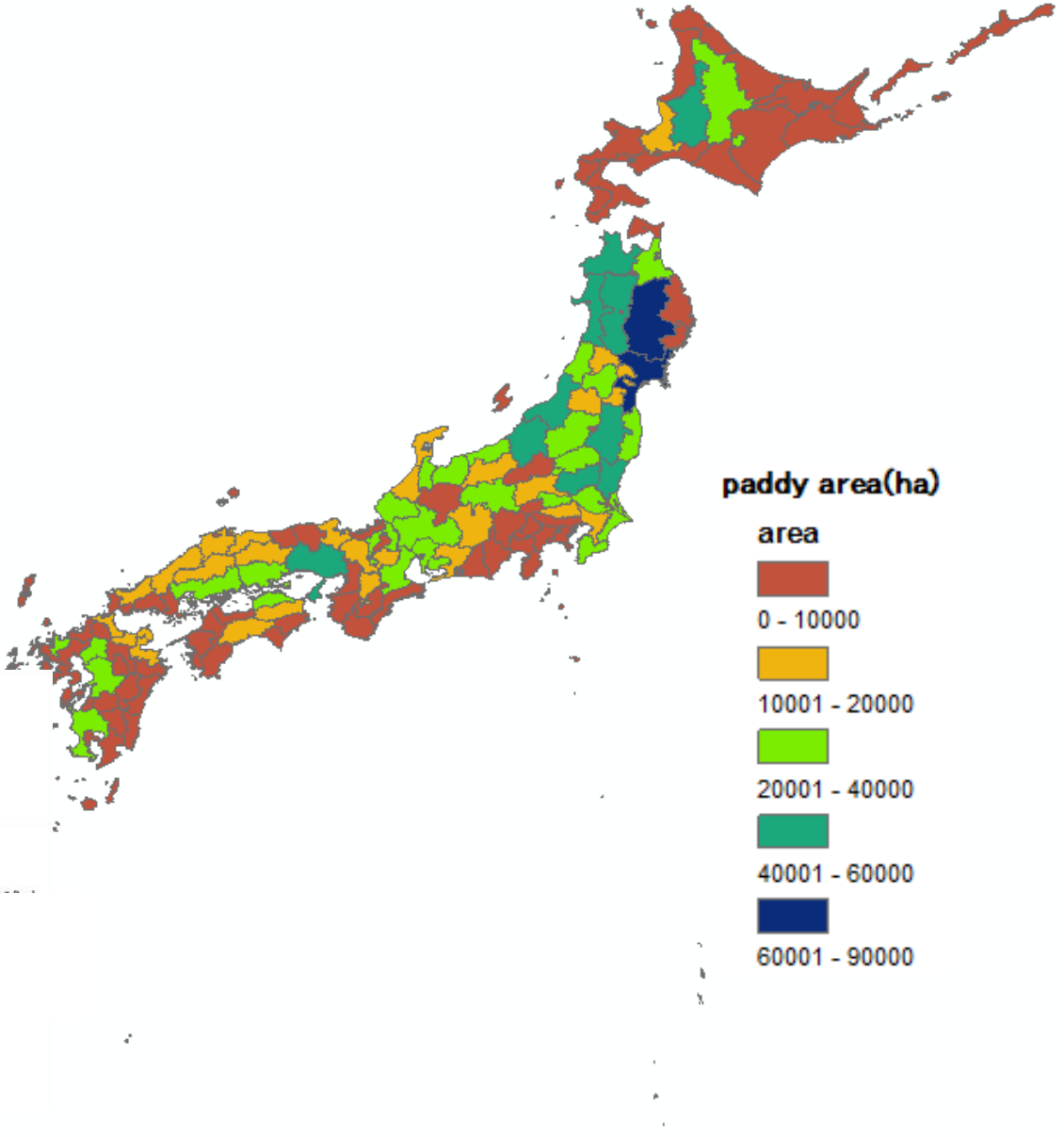


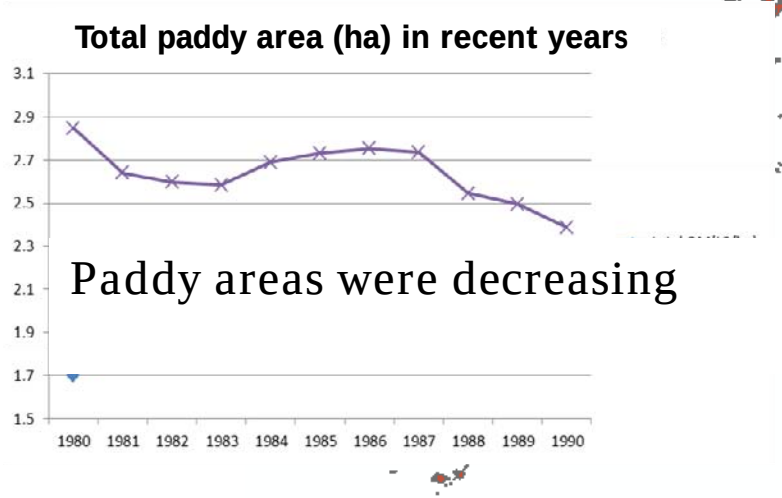
Database Construction



Paddy area

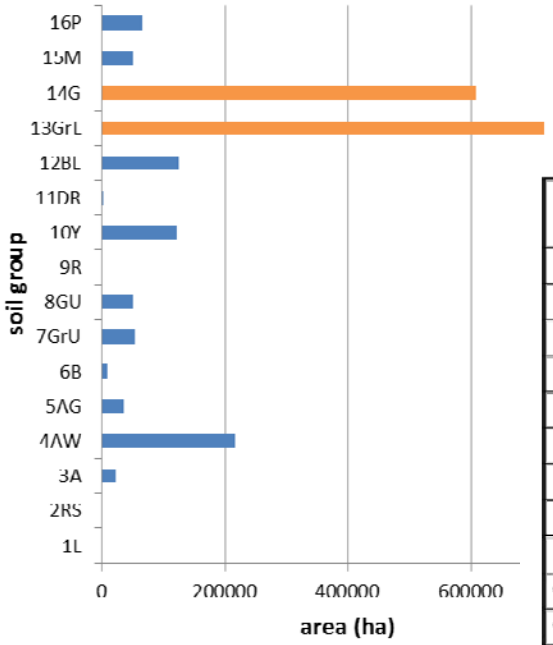
- 2,080,000(ha), in 1990





Paddy areas were decreasing

Soil Type and properties for inputs



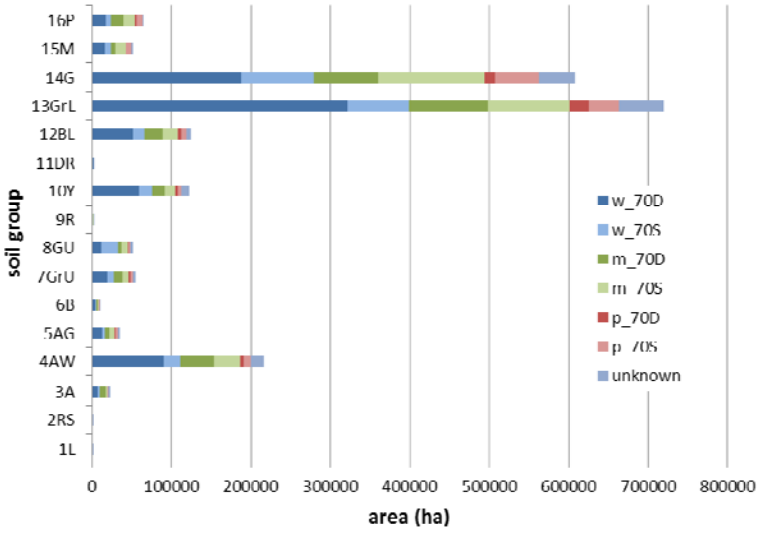
More than 60% of paddy area is occupied by GrL and G. Biologically reducible iron is estimated from free iron oxide concentration.

Soil group <landuse: paddyfield>	US Soil taxonomy	SOC/soil (g/g)	Clay/soil (g/g)	pH	BulkDensity (Mg/m^3)	Fe_br (mol/kg)
1 Lithosols (L)	Lithic Udorthents	0.015	0.166	5.70	1.24	0.091
2 Sand-dune, Regosols (RS)	Udipsamments	0.008	0.008	5.80	1.34	0.110
3 Andosols (A)	Dystrandepts	0.059	0.158	5.88	0.83	0.110
4 Wet Andsols (AW)	Aquic Dystrandept	0.052	0.198	5.89	0.83	0.135
5 Gleyed Andosols (AG)	Andaquepts	0.045	0.288	5.73	0.79	0.112
6 Brown Forest soils (B)	Dystrochrepts	0.025	0.403	5.58	1.06	0.127
7 Gray Upland soils (GrU)	Haplaquepts	0.022	0.208	5.73	1.09	0.099
8 Gley Upland soils (GU)	Haplaquepts	0.024	0.262	5.55	1.02	0.120
9 Red soils (R)	Hapludults	0.016	0.234	5.70	1.07	0.077
10 Yellow soils (Y)	Hapludults	0.023	0.228	5.86	1.09	0.118
11 Dark Red soils (DR)	Rhodudults	0.016	0.280	6.20	1.30	0.192
12 Brown Lowland soils (BL)	Udifluvents	0.023	0.223	5.70	1.08	0.118
13 Gray Lowland soils (GrL)	Haplaquepts	0.021	0.195	5.84	1.09	0.101
14 Gley soils (G)	Haplaquents	0.025	0.180	5.77	1.01	0.106
15 Muck soils (M)	Saprists	0.037	0.256	5.77	0.94	0.116
16 Peat soils (P)	Fibrists / Hemists	0.052	0.268	5.56	0.84	0.099

64%

Field Drainage condition

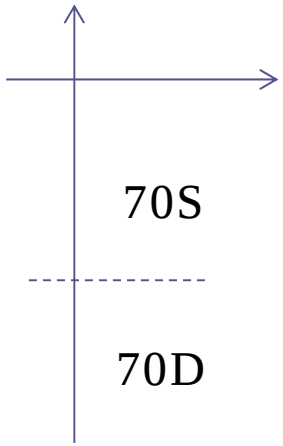
- Considering the drainage facilities and crop growth condition, paddy drainage condition was classified by a national survey by MAFF, using 3 categories of surface drainage rate as well as 2 categories of ground water level (GWL).
- We assigned drainage rate of 15, 10 and 5 mm per day.



Surface drain rate	GWL	Rice growth	Upland crop	Mechanical workability
Well drained	70cm deep (70D)	Fine	Fine	Fine
15mm/day	70cm shallow (70S)	Fine	Poor	Poor
Moderate drained	70cm deep	Fine	Fine	Fine
10mm/day	70cm shallow	Fine	Poor	Poor
Poor drained	70cm deep	poor	poor	Poor
5mm/day	70cm shallow	poor	Poor	Poor

Field Water Capacity

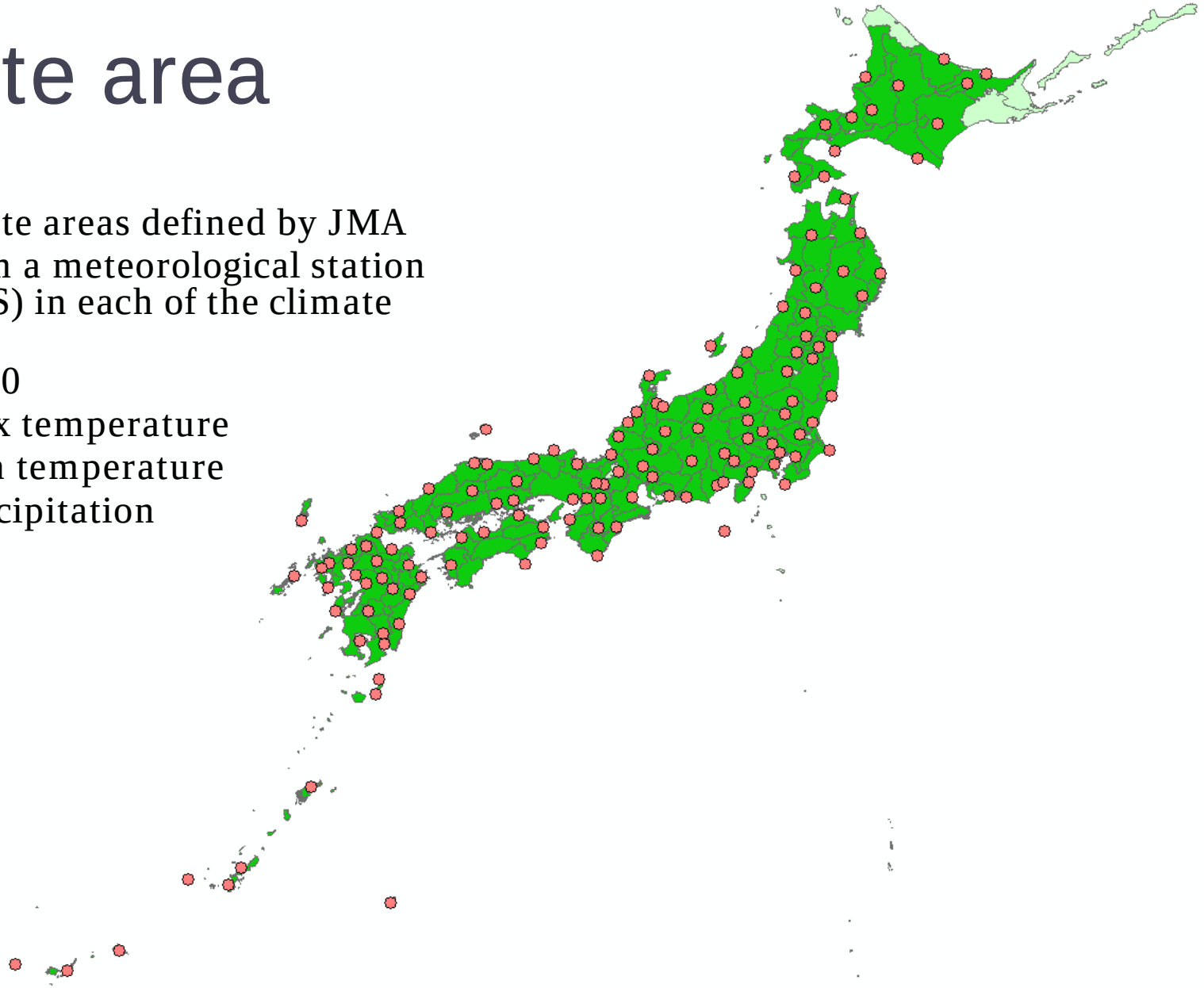
- FWC was related to GWL.
- The difference in GWL between 70D and 70S was assumed to be 10 cm.
- FWC of 70D → pF1.5 water contents.
- FWC of 70S →pF1.33 water contents.



Soil type	GWL70S	GWL70D
1L	0.86	0.823
2RS	0.729	0.693
3A	0.859	0.835
4AW	0.856	0.835
5AG	0.882	0.855
6B	0.78	0.753
7GrU	0.861	0.844
8GU	0.86	0.839
9R	0.639	0.61
10Y	0.827	0.809
11DR	0.75	0.716
12BL	0.84	0.821
13GrL	0.836	0.817
14G	0.855	0.839
15M	0.858	0.842
16P	0.856	0.833

Climate area

- 136 climate areas defined by JMA
- Data from a meteorological station (AMeDAS) in each of the climate areas
- 1980-1990
- Daily max temperature
- Daily min temperature
- Daily precipitation

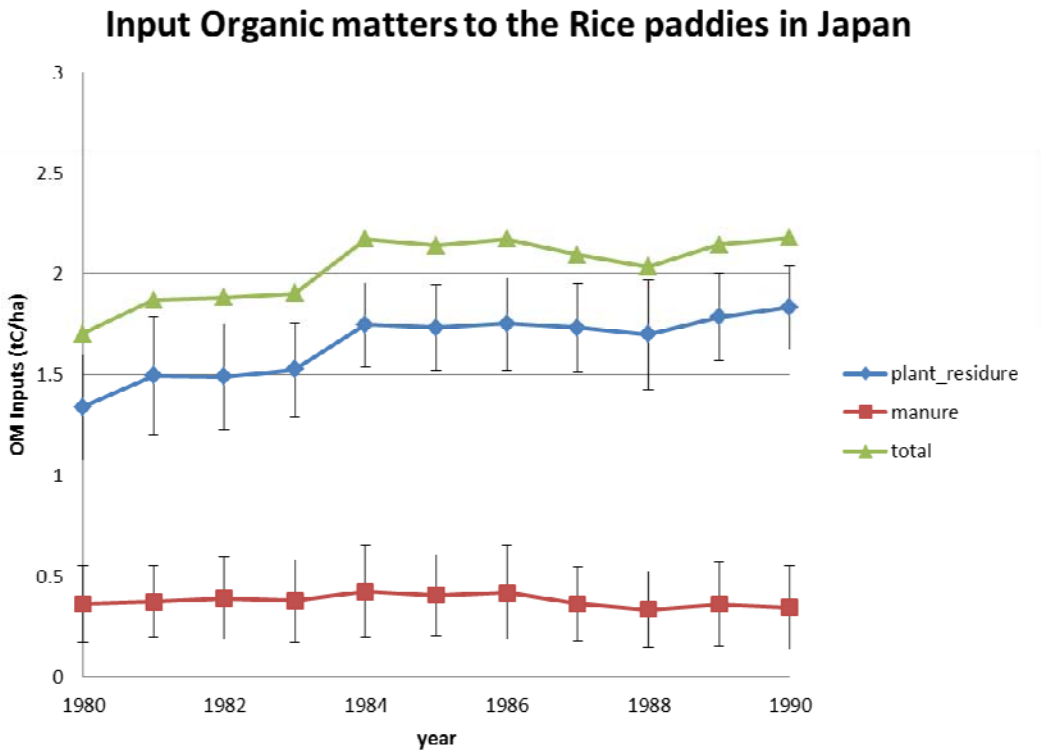


Farming management were defined for each of the 136 climate areas

- Rice Cultivar
- Transplanting date
- Harvesting date
- Tillage
- Fertilization
- Organic matter application
- Irrigation
  - Farming management data were compiled from crop calendars published by JA or statistical survey.
  - Single midseason drainage was assumed when irrigation data were not available.

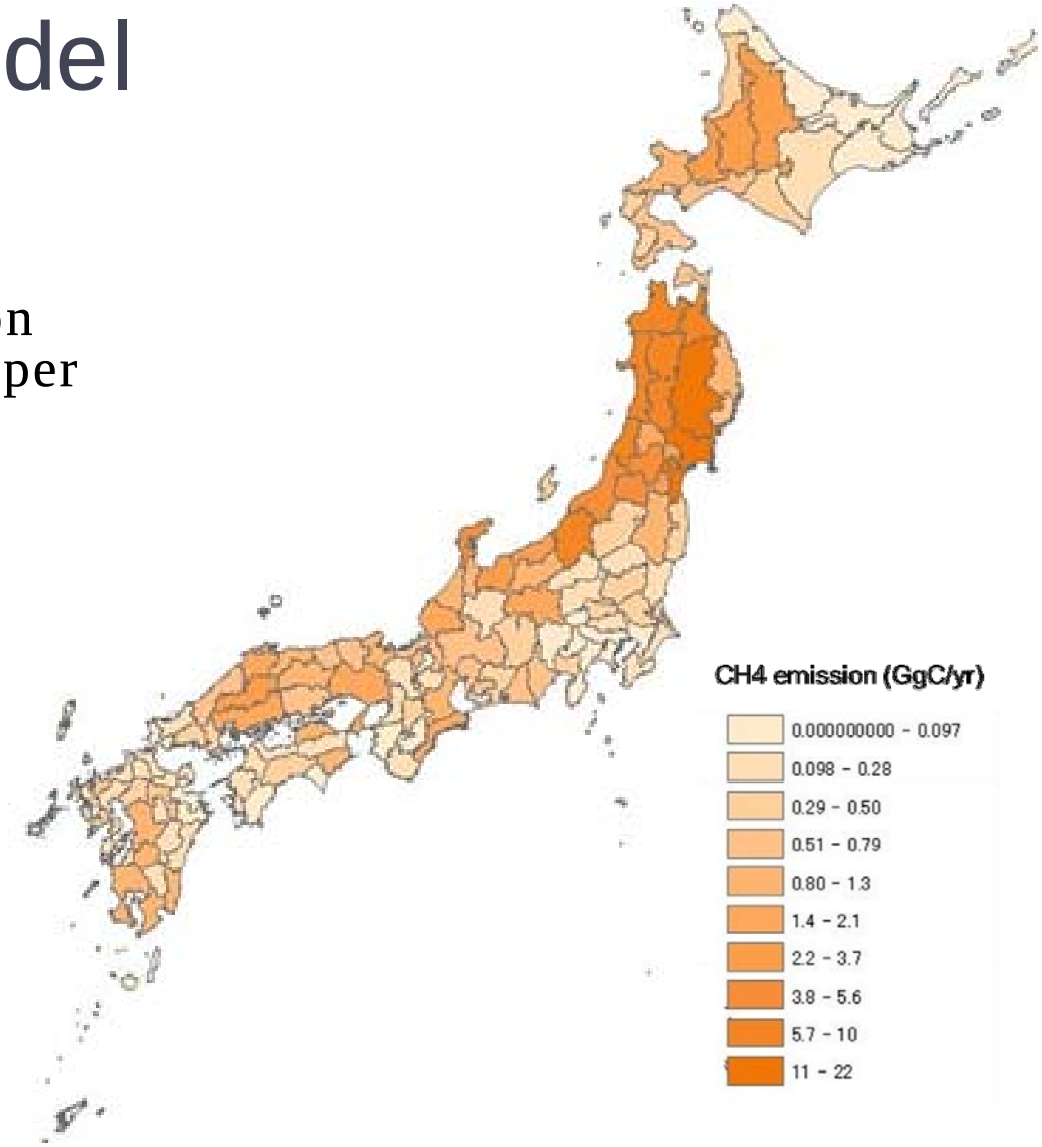
Manure application

- Average organic matter application rate for each prefecture estimated by MAFF.
- The amount of OM (plant residue) were increasing from 1980 to 1990.



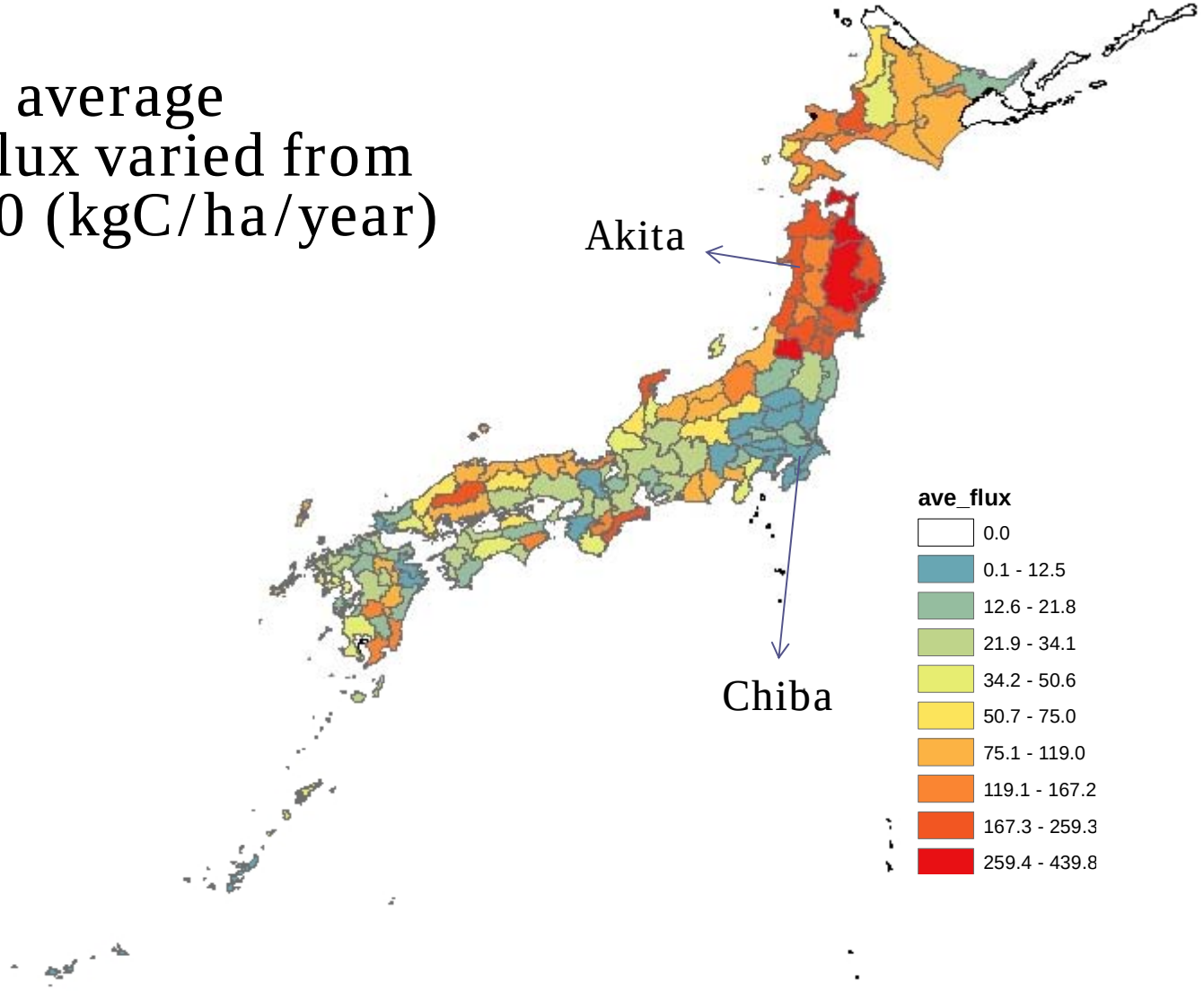
Results: Total Methane emission 1990 by DNDC-Rice model

- Estimated Methane emission in 1990 was about 188 GgC per year.

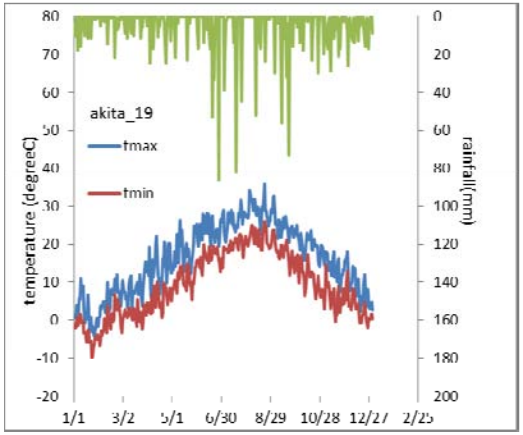


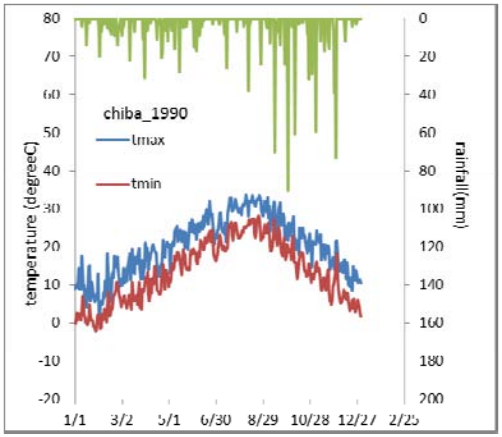
Results: average methane flux

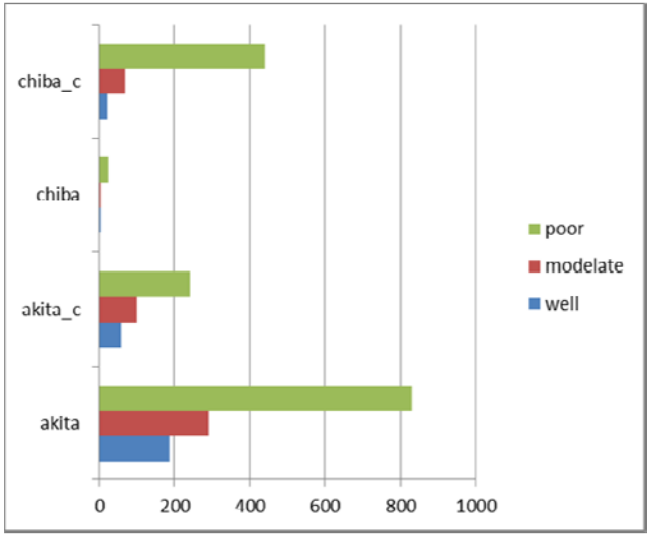
- Estimated average methane flux varied from 0.12 to 440 (kgC/ha/year)



Effect of Climate to methane:





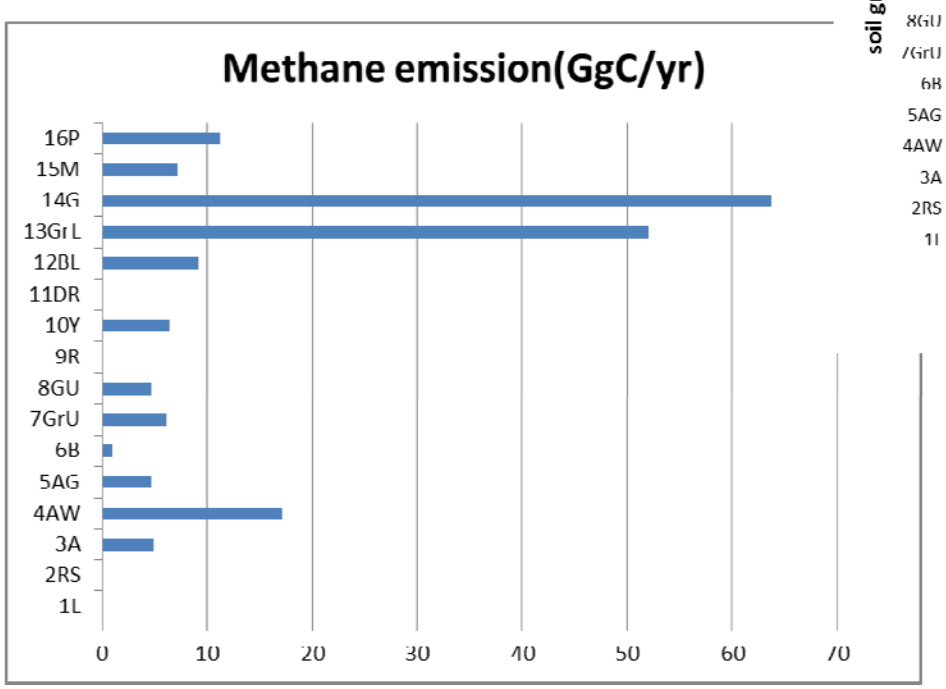


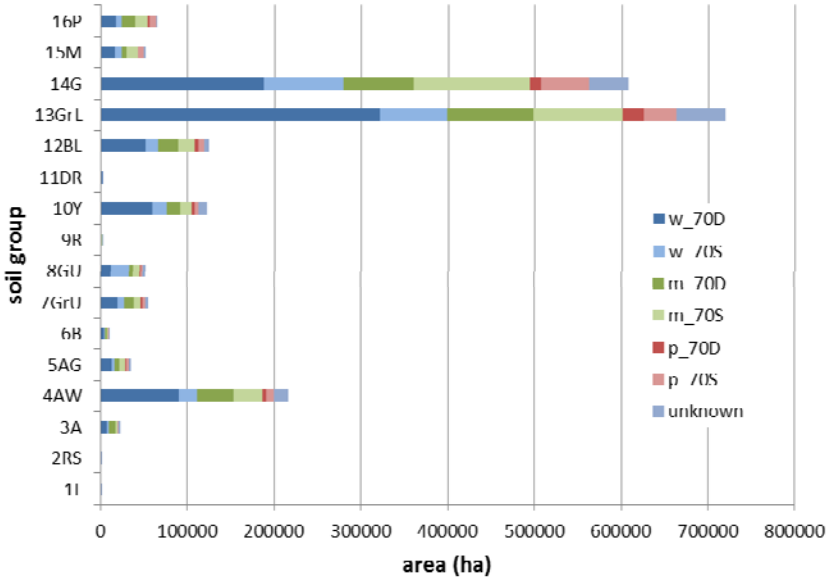
Akita
T:12.6℃
Pr:1891 (mm)

Chiba
T:16.7℃
Pr:1264 (mm)

By exchanging the climate data,
Average flux of Akita becomes 0.3 times
Average flux of Chiba becomes 7-18 times

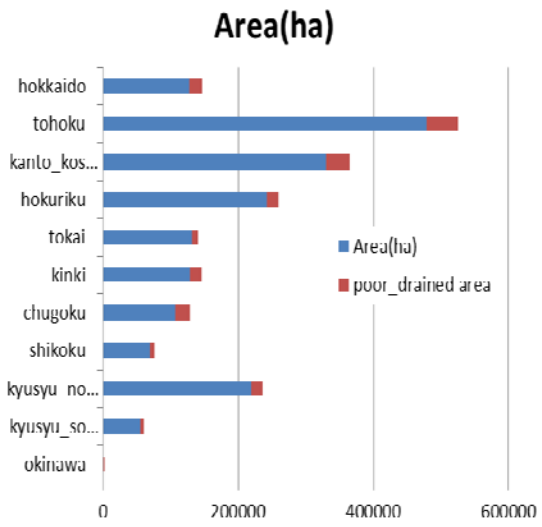
Result: Soil type and methane emission

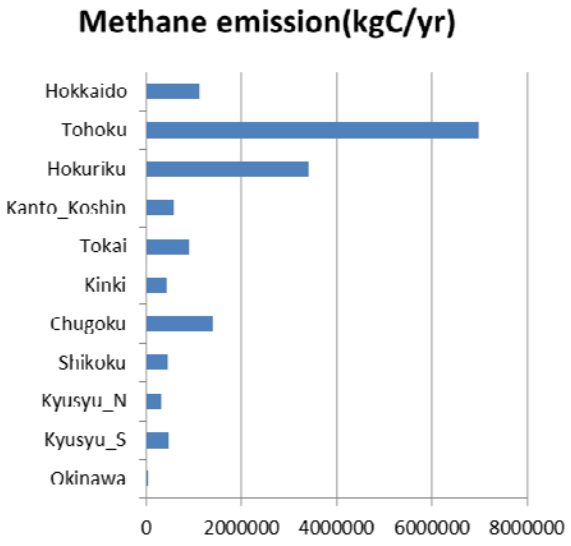


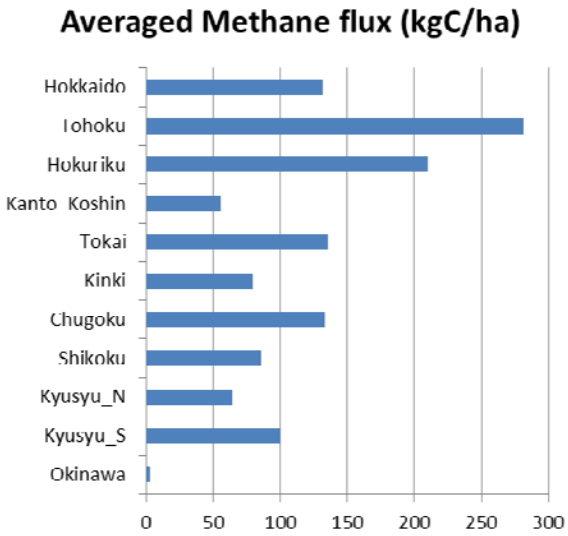


- Total paddy Area
- Poorly-drained area

Regional comparison: Area and methane emission & flux







Comparison: GIO study

	GIO(2011)		DNDC-Rice
total area(million ha)	2.055		2.084
	Area ratio(%)		
Andosol (3,4,5)	13.06		13.19
Yellow soil (1,6,7,8,9,10,11)	11.30		11.56
Lowland soil (2,12,13)	40.82		40.53
Gley soil (14)	28.94		29.16
Peat (15,16)	5.85		5.56
total CH4 (Gg-CO2)	6,960		5,264
	CH4 flux(kg C/ha)		
	straw	manure	both
Andosol (3,4,5)	63.8	56.9	126.8
Yellow soil (1,6,7,8,9,10,11)	160.5	109.5	100.0
Lowland soil (2,12,13)	143.3	114.8	113.0
Gley soil (14)	133.5	103.5	130.5
Peat (15,16)	201.0	153.8	149.0

Summary

- Methane emission in 1990 was estimated by a process-based biogeochemistry model, DNDC-Rice (Tier III method).
- Field drainage rate was considered in addition to the soil type.
- Estimated methane emission was about 188GgC, per 2.08million ha in 1990.
- Further study for uncertainty assessment is necessary.