Mitigation of methane emissions from paddy fields by prolonging mid-season drainage

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### Contribution of major Greenhouse gases for Global warming

#### Comparison in radiative forcing of long life GHGs in 2005

<table>
<thead>
<tr>
<th>Gas</th>
<th>Contribution</th>
<th>Radiative Forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>63%</td>
<td>0.34 W m⁻²</td>
</tr>
<tr>
<td>CH₄</td>
<td>18%</td>
<td>0.16 W m⁻²</td>
</tr>
<tr>
<td>N₂O</td>
<td>6%</td>
<td>0.48 W m⁻²</td>
</tr>
<tr>
<td>Others</td>
<td>13%</td>
<td>0.16 W m⁻²</td>
</tr>
</tbody>
</table>

**Global Warming Potential (GWP-100yrs)**

- CO₂: 1
- CH₄: 25
- N₂O: 298
- CFC: >4,750
- HCFC: >77
- SF₆: 22,800

*(GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. A GWP is calculated over a specific time interval, commonly 20, 100 or 500 years.*

IPCC AR4-WG1 (2007)
From 1980th, CH$_4$ emission from rice paddy fields have been observed in Japan. Much information of emission patterns and its control factors were reported.

According to the nationwide study, CH$_4$ emission factors for many soil types or types of applied organic matters were assessed (6.1～26.8 g/m$^2$・yr)

CH$_4$ emission from rice field in whole Japan was estimated, accounting for about 30% of anthropogenic CH$_4$ emission.

New methods for reducing CH$_4$ emission from rice field is strongly needed. This must keep the levels of productivity, labor, and costs.

Anthropogenic CH$_4$ emission from Japan

CH$_4$ : 920,000 t
(CO$_2$ equivalent: 19,290,000 t)
Previous report of altering water management

Continuous flooding | Intermittent drainage

Day after flooding

From Yagi et al., 1996

Continuous flooding: 9.5 g/m²

Intermittent drainage: 5.2 g/m² (Ibaraki pref.)

They showed the possibility for reducing much CH₄ emission by simple change of water management (for Ibaraki pref.).

Such method is considered to be easily applicable method for farmers, because little additional labor and costs.
Conventional Water Management in Japanese Rice Cultivation

- Most of Japanese paddy fields are managed by intermittent-irrigation scheme

- in order to give a high yield of rice
  - by reducing numbers of ineffectual tillers
  - by enhancing root activities
The aim of this study is to establish the effective water managements for many Japanese regions that mitigate CH$_4$ emission from rice paddy fields (by lengthening mid-season drainage).

BUT, alternative water managements should be based on conventional one for each region and soil type.

(It should be intended for reasonable for each region with concerning the climate, water facility, or yield.)
CH$_4$ in paddy soil is emanated by the activities of anaerobic bacteria which is called methane producer through reduction of CO$_2$ or decomposition of acetic acid. It is effective to prolong the drainage period for reducing CH$_4$ emission from rice paddy.
Observation sites

Observation was conducted at paddy fields belonging to 8 prefectural agricultural research institutes

- Yamagata pref. (Yamagata and Tsuruoka)
- Fukushima pref. (Koriyama)
- Niigata pref. (Nagaoka)
- Gifu pref. (Gifu)
- Aichi pref. (Nagakute)
- Tokushima pref. (Ishii)
- Kumamoto pref. (Koushi)
- Kagoshima pref. (Minami Satsuma)

Legend:
- Gray Upland soils
- Gley soil
- Gray Lowland soils
- Wet Andosol
Observation sites

Map showing locations in Japan:
- Shonai
- Niigata
- Yamagata
- Gifu
- Aichi
- Tokushima
- Kumamoto
- Kagoshima
Method

- 3 to 5 water managements for each site are tested to understand the efficiency for reducing CH$_4$ emissions.
- CH$_4$ and N$_2$O emissions were measured by manual closed chamber method.
- CH$_4$ and N$_2$O concentrations were analyzed by GC-FID and GC-ECD.
Experimental Design (Waterlogged period)

- **Shonai**: 7d Front-loaded
- **Yamagata**: 7d → 14d
- **Fukushima**: 14d → 21d or 28d
- **Niigata**: 10d → 14d or 24d
- **Gifu**: 7d or 13d → 20d
- **Aichi**: 6d → 9d or 13d
- **Tokushima**: 7d → 14d or 21d
- **Kumamoto**: 7d → 10d
- **Kagoshima**: 5d → 10d or 15d

Blue line: Conventional  Green • Orange: Altered

**Extended**
Waterlogged period

Date (from Spring to Fall)

CH$_4$ flux (mg-CH$_4$ m$^{-2}$ d$^{-1}$)
On average 30.5% of CH$_4$ emission was reduced (Blue colored).
On average 30.5% of CH$_4$ emission was reduced (Blue colored).

At the site where no organic matter (rice straw) was incorporated to the soil before transplanting, the effect of altering water management was small.
### Examples of Results (CH₄ flux in 2008)

#### Yamagata

<table>
<thead>
<tr>
<th>Date</th>
<th>6/1/08</th>
<th>7/1/08</th>
<th>8/1/08</th>
<th>9/1/08</th>
<th>10/1/08</th>
<th>11/1/08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm/day)</td>
<td>0</td>
<td>40</td>
<td>80</td>
<td>0</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>CH₄ flux (g-CH₄/m²)</td>
<td>(Conventional)</td>
<td>57.0</td>
<td>(Altered 1)</td>
<td>36.1</td>
<td>- 37 %</td>
<td>(Altered 2)</td>
</tr>
<tr>
<td>Yield (Kg/10a)</td>
<td>(Conventional)</td>
<td>667</td>
<td>(Altered 1)</td>
<td>643</td>
<td>- 4 %</td>
<td>(Altered 2)</td>
</tr>
<tr>
<td>Emission pattern</td>
<td>Both</td>
<td>667</td>
<td>Last half</td>
<td>701</td>
<td>662</td>
<td>First half</td>
</tr>
</tbody>
</table>

#### Fukushima

<table>
<thead>
<tr>
<th>Date</th>
<th>6/1/08</th>
<th>7/1/08</th>
<th>8/1/08</th>
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<th>10/1/08</th>
<th>11/1/08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm/day)</td>
<td>0</td>
<td>40</td>
<td>80</td>
<td>0</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>CH₄ flux (g-CH₄/m²)</td>
<td>(Conventional)</td>
<td>28.3</td>
<td>(Altered 1)</td>
<td>18.6</td>
<td>- 34 %</td>
<td>(Altered 2)</td>
</tr>
<tr>
<td>Yield (Kg/10a)</td>
<td>(Conventional)</td>
<td>701</td>
<td>(Altered 1)</td>
<td>662</td>
<td>- 6 %</td>
<td>(Altered 2)</td>
</tr>
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</table>

#### Gifu

<table>
<thead>
<tr>
<th>Date</th>
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<th>7/1/08</th>
<th>8/1/08</th>
<th>9/1/08</th>
<th>10/1/08</th>
<th>11/1/08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm/day)</td>
<td>0</td>
<td>40</td>
<td>80</td>
<td>0</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>CH₄ flux (g-CH₄/m²)</td>
<td>(Conventional)</td>
<td>3.9</td>
<td>(Altered 1)</td>
<td>2.4</td>
<td>- 40 %</td>
<td>(Altered 2)</td>
</tr>
<tr>
<td>Yield (Kg/10a)</td>
<td>(Conventional)</td>
<td>499</td>
<td>(Altered 1)</td>
<td>429</td>
<td>- 14 %</td>
<td>(Altered 2)</td>
</tr>
</tbody>
</table>

** ** Lines at the bottom of the figures indicate the waterlogged period for each water management.

** p <0.01 (Compared to conventional management (from the start of MD to harvest)
### Examples of Results (CH₄ flux in 2008)

<table>
<thead>
<tr>
<th></th>
<th>Yamagata</th>
<th>Fukushima</th>
<th>Gifu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CH₄ flux</strong> (g-CH₄/m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Season)</td>
<td>(Conventional)</td>
<td>57.0</td>
<td>28.3</td>
</tr>
<tr>
<td></td>
<td>(Altered 1)</td>
<td>36.1 ⏞ 37 %</td>
<td>18.6 ⏞ 34 %</td>
</tr>
<tr>
<td></td>
<td>(Altered 2)</td>
<td>48.2 ⏞ 16 %</td>
<td>11.8 ⏞ 58 %**</td>
</tr>
<tr>
<td><strong>Yield</strong> (Kg/10a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Conventional)</td>
<td>667</td>
<td>701</td>
</tr>
<tr>
<td></td>
<td>(Altered 1)</td>
<td>643 ⏞ 4 %</td>
<td>662 ⏞ 6 %</td>
</tr>
<tr>
<td></td>
<td>(Altered 2)</td>
<td>673 ⏞ 1 %</td>
<td>587 ⏞ 16 %</td>
</tr>
</tbody>
</table>

**Emission pattern**
- Both
- Last half
- First half

!! Lines at the bottom of the figures indicate the waterlogged period for each water management.
** p <0.01 (Compared to conventional management (from the start of MD to harvest)
Our experiments indicate that seasonal CH$_4$ emission and the net GWPs (CH$_4$ + N$_2$O) can be suppressed to $69.5 \pm 3.4$ (SE)$\%$ and $72.0 \pm 3.1$% while maintaining grain yield as high as $96.2 \pm 2.0$% by prolonging MD.
No rain days during mid-season drainage was important factor to control seasonal CH$_4$ emission.
If the soil get drier in MD period, seasonal CH$_4$ emission is lower.
Summary 1

- Seasonal CH$_4$ emissions were reduced at most of the observation sites by altering water managements
  
  (8 of 9 sites; from 12 to 55 % reduction)

  → Lengthening mid-season drainage is effective for reducing CH$_4$ for major types of Japanese soils
  
  Also, this method is easily acceptable for the farmer

- At all sites, increase of N$_2$O emission during mid-season drainage is negligible.
Summary 2

- Reduction of seasonal CH$_4$ emissions was affected by the degree of soil dryness during mid-season drainage.

- Average grain yield was maintained as high as 96.2% for altered water managements compared to the conventional methods.
Application of research outcomes

- Now, our research outcomes contributed to make a manual to reduce CH$_4$ emissions from rice paddy field which is ready to be circulated to farmers.

  (now only in Japanese)

Also, our results will be used for the calculation of National greenhouse Inventory of Japan.
Thank you for your attention.
Acknowledgement

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