Acid Rain Links to Methane Emissions from Wetlands

Vincent Gauci
The Global Methane Budget

- Natural Wetlands: 22%
- Rice paddies: 20%
- Enteric Fermentation: 15%
- Oceans: 2%
- Hydrates: 1%
- Termites: 7%
- Coal: 7%
- Natural Gas: 8%
- Landfill: 7%
- Freshwater: 1%
- Biomass Burning: 10%
Atmospheric Methane Growth Rate

Dlugokencky et al 1998
The Sulfur Cycle (values in Tg-S/year)  
(modified from Graedel and Crutzen 1993)
Distribution of Wetland Ecosystems

E. Mathews and I. Fung (1987)
Modelled total S-dep
1960-2030

Global interpolated distribution of total (wet + dry) S-deposition (mg/m²/year) for the years 1960 (a), 1990 (b) and 2030 (C)
How does the addition of sulfate affect the rate of methane emission

• Microbially mediated processes.

• Two anaerobic microbial communities (sulfate reducers and methane producers) are in direct competition over limiting substrates
Microbial Competition

Sulfate absent

M

substrate

Acetate

H₂ + CO₂

CH₄ + CO₂

CH₄

Sulfate present

M

substrate

Acetate

H₂ + CO₂

CO₂ + H₂S
Previous work investigating the link between sulphate and methane emission

- Single, large fertilisation doses \((10^3 \text{ kg/ha})\) rice paddies.
- Lab peat cores in controlled environments (single ‘pollution’ doses of around \(50\text{kg/ha}\))
- Continuous pollution level doses - (limited data)
Methods

- Field location
- Experimental design
- Static Chamber method
Moidach More

Inset

Study Site
Chamber Design

Sample syringe

Suba-seal

6mm acrylic

Neoprene ‘O’ ring

Polypropylene pipe (300mm ID)
Relationship between the number of sedge shoots and methane flux

![Graph showing the relationship between sedge shoot number and methane flux with a regression line and R^2 value of 0.4775.](image-url)
Experimental Design

**KEY**
- Controls
- 25 Kg SO₄-S
- 50 Kg SO₄-S
- 100 Kg SO₄-S
- 50 Kg SO₄-S (single)

**TREATMENT**

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<thead>
<tr>
<th>BLOCK 1</th>
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Relationship between the number of sedge shoots and pre-treatment methane flux

\[ R^2 = 0.4775 \]
P-value *(Control vs. Treatment)*TREATMENTMean CH\textsuperscript{4} Flux (± s.e.) (mg CH\textsuperscript{4} .m\textsuperscript{-2}.day\textsuperscript{-1})*(a)(b) Pre-treatment

<table>
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<tr>
<th>TREATMENT</th>
<th>Mean CH\textsuperscript{4} Flux (± s.e.) (mg CH\textsuperscript{4} .m\textsuperscript{-2}.day\textsuperscript{-1})</th>
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Pre-treatment (21st May – 25th June 1997)

n = 25

Control

21.2 (3.5)

25 kg SO\textsubscript{4}2- S designate

21.3 (3.4)

0.98

0.95

50 kg SO\textsubscript{4}2- S designate

21.0 (2.9)

0.96

0.30

100 kg SO\textsubscript{4}2- S designate

19.8 (1.9)

0.74

0.61

Post-treatment

year 1.

(2nd July – 17th Dec 1997)

n = 70

Control

23.8 (2.7)

25 kg SO\textsubscript{4}2- S. ha\textsuperscript{-1}.yr\textsuperscript{-1}

22.1 (2.3)

0.62

0.48

50 kg SO\textsubscript{4}2- S. ha\textsuperscript{-1}.yr\textsuperscript{-1}

23.4 (2.2)

0.91

0.11

100 kg SO\textsubscript{4}2- S. ha\textsuperscript{-1}.yr\textsuperscript{-1}

18.6 (1.7)

0.09

0.07

Post-treatment

year 2.

(Year 1998 (31st March – 11th Nov 1998))

n = 130

Control

64.8 (5.4)

(16.8)

25 kg SO\textsubscript{4}2- S. ha\textsuperscript{-1}.yr\textsuperscript{-1}

48.8 (3.8)

(10.7)

<0.01

<0.001

50 kg SO\textsubscript{4}2- S. ha\textsuperscript{-1}.yr\textsuperscript{-1}

58.8 (4.5)

(13.2)

0.35

<0.001

100 kg SO\textsubscript{4}2- S. ha\textsuperscript{-1}.yr\textsuperscript{-1}

45.2 (3.2)

(9.8)

<0.001

<0.001
Total monthly rainfall (a), peat temperature 10 cm below water table (b) and mean water-table position (c) over the course of the experiment.
% variation in (treatment) methane flux and mean water table in 1997 - 1998

Date

Mean % variation in treatment flux

mean water table/cm

3 per. Mov. Avg. (mean CH4 variation)
3 per. Mov. Avg. (water table)
Measured data (•) and modelled data surface showing the relationship between treatment effect, temperature and water table (specific to Moidach More where water-table varied temporarily). Heavy lines excludes areas for which no data is available.
Porewater Chemistry

** P< 0.01  * P < 0.05

Porewater [CH₄], µM

Porewater [SO₄-S], µM

Depth below peat surface / cm

control  50 Kg SO₄-S
What are the implications for global atmospheric methane in the future?

Method:

- Tropospheric S simulation in GISS GCM
- CH$_4$ from natural wetlands in GISS GCM
- Estimation of rice CH$_4$ using IPCC methodologies
Modelled global S - deposition

Global interpolated distribution of total (wet + dry) S-deposition (mg/m²/year) for the years 1960 (a), 1990 (b) and 2030 (C) and areas impacted with S in excess of the 15kg/ha/year threshold for the same years (i,ii,iii respectively).
Natural wetlands

$\text{CH}_4$ emissions

1960-2030
Modelled Northern Wetland CH$_4$ Emissions
As Affected by S deposition
(annual CH$_4$ emissions /Tg)

<table>
<thead>
<tr>
<th>Year</th>
<th>Nothern Wetland (&gt;50 deg N$^\text{th}$) CH$_4$ flux/Tg</th>
<th>CH$_4$ flux with S -deposition (Tg)</th>
<th>% flux reduction</th>
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<tr>
<td>1960</td>
<td>33.9</td>
<td>29.2</td>
<td>13.9</td>
</tr>
<tr>
<td>1990</td>
<td>39.3</td>
<td>32.4</td>
<td><strong>17.3</strong></td>
</tr>
<tr>
<td>2030</td>
<td>46.2</td>
<td>39.1</td>
<td>15.4</td>
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Estimated Rice Paddy

Methane emissions

Changes in rice production only

Changes in rice production + S-dep