Alpine soil as a methane sink: controlling factors and fire effects.

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Does fire and climate change affect CH$_4$ oxidation?

What controls CH$_4$ oxidation?
Methanotrophic bacteria

• Oxidizes (consumes) methane \((CH_4)\); consuming 3-10% of emissions

• Only occurs in aerobic soils \((O_2)\)

\[
CH_4 + 2O_2 \xrightarrow{k} CO_2 + 2H_2O
\]
Atmospheric \( CH_4 \) climate change oxidation (by methanotrophs) affects soil properties and processes.
Climate Change

Atmospheric CH₄

SOIL properties & processes

CH₄ Oxidation
(By methanotrophs)
Atmospheric CH$_4$ has increased....

![Graph showing the increase in CH$_4$ over time, with a 75% increase from 1800 to 2000.](IPCC TAR, 2001)
Atmospheric CH$_4$ has increased....

1997-2008

Rigby et. al. 2008

....and is still increasing?
Atmospheric CH$_4$ has increased….

… and is still increasing?

Rigby et. al. 2008
Climate Change

Atmospheric CH$_4$

SOIL properties & processes

CH$_4$ Oxidation (By methanotrophs)
21% of Australia’s total net CO₂ equivalent greenhouse gas emissions

CH₄
21% (1.8ppm)

CO₂
74% (391 ppm)

N₂O
4%

HFCs & PFCs
1%

Measured using Kyoto accounting provisions, National Greenhouse Gas Inventory 2006
CH$_4$ contributes to **20%** of temp ↑

(a) Global average surface temperature

IPCC AR4 Synthesis Report  Fig 1.1
Atmospheric $\text{CH}_4$ oxidation (by methanotrophs) affects soil properties & processes, which in turn impact climate change.
## Fire affects Alpine Ash soil

<table>
<thead>
<tr>
<th>Mean (± s.e)</th>
<th>Pre-Fire Nov 2002</th>
<th>~1 year post fire April 2004</th>
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<td><strong>pH</strong></td>
<td>4.58 (0.28)</td>
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Data from Robert Simpson’s PhD thesis
## Fire affects Alpine Ash soil

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Why study methane oxidation?……

- Powerful GHG contributing to climate change
  Changing atmospheric concentrations?

- Australian soils are important sink. How will this sink be effected by change?
  Little research
  Sink NOT accounted for in GHG inventory
  Controlling factors UNKNOWN

……How do soil properties effect this sink?
WHICH properties
MAGNITUDE of their effects

H₂O, Temp

Atmospheric CH₄ conc.

SOIL properties

CH₄ Oxidation
Alpine ash
*(Eucalyptus delegatensis)*
Montane forests

- Burnt 2003, Canopy killed
- Burnt 2003, canopy not killed
- Burnt 2003 & 06, canopy not killed
Part 1: Field Studies
## Comparisons between ecosystems

<table>
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<tr>
<th>Ecosystem</th>
<th>CH$_4$ ox rate $\mu$g CH$_4$ m$^{-2}$ h$^{-1}$</th>
<th>Reference (example)</th>
</tr>
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<tr>
<td>Forest Boreal</td>
<td>65</td>
<td>Bradford <em>et al.</em> 2001</td>
</tr>
<tr>
<td>Alpine Ash</td>
<td>59</td>
<td><em>This Study</em></td>
</tr>
<tr>
<td>Pasture-Temperate</td>
<td>55</td>
<td>Meyer <em>et al.</em> 2001</td>
</tr>
<tr>
<td>Forest Temperate</td>
<td>44</td>
<td>Castro <em>et al.</em> 1995</td>
</tr>
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<td>Grassland</td>
<td>44</td>
<td>Moiser <em>et al.</em> 1996</td>
</tr>
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<td>Forest sub/tropical</td>
<td>24</td>
<td>Prieme &amp; Christensen 1997</td>
</tr>
<tr>
<td>Desert</td>
<td>24</td>
<td>Striegl <em>et al.</em> 1992</td>
</tr>
<tr>
<td>Savannas -global</td>
<td>20</td>
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</tr>
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<td>Pasture-tropical</td>
<td>8</td>
<td>Steudler <em>et al.</em> 1996</td>
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</table>
CH$_4$ oxidation was the lowest at sites more severely or recently burnt

Measured March 2007
Soil ammonium was the highest at sites more recently burnt.
Methane oxidation was the **lowest** at sites more recently burnt

Soil ammonium was **highest** at sites more recently burnt.
Methane decreases as ammonium increases. However, this relationship is not statistically significant.
Methane decreases as ammonium increases. However, this relationship is not statistically significant.
Part 2: Laboratory Studies
Ammonium inhibits methane oxidation

Methane oxidation (µg CH₄ l⁻¹ kg⁻¹ d.w.) vs. Ammonium (µg l⁻¹)

Methane oxidation ↘ soil ammonium ↗
WHICH properties
MAGNITUDE of their effects

$H_2O$  
Temp

SOIL properties

Atmospheric $CH_4$ conc.

$CH_4$ Oxidation
Important controlling factors

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<th>Property</th>
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<td>-</td>
</tr>
<tr>
<td>- high &amp; low</td>
<td>↓</td>
</tr>
<tr>
<td>NH₄ conc ↑</td>
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</tr>
<tr>
<td>CH₄ conc ↑</td>
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- Temperature and bulk density has little effect
- pH had a small although not significant effect except at the extreme pH values.
Laboratory studies

✓ Useful for determining the effect of an individual soil properties and interactions between soil properties

✗ May not replicated field conditions
Laboratory studies

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✗ May not replicated field conditions.

Field Studies

✗ Difficult to distinguish the effects of individual soil properties.

✓ Required to verify laboratory results and test models and assumptions.

✓ Determine and compare CH₄ oxidation rates at different sites and locations (i.e., different vegetation, conditions, burn histories).
Does fire and climate change affect $CH_4$ oxidation?

What controls $CH_4$ oxidation?
Fire and climate change will effect CH$_4$ oxidation
Fire and climate change **WILL** effect CH$_4$ oxidation

This is a **COMPLEX** system!!

The **direction**, **magnitude** and **duration** of this effect is dependent on:

- Fire properties
- Soil conditions and type
- Soil resilience and recovery
- Vegetation; type, diversity, & growth rate
- Bacterial diversity and population size
The Next Steps

Laboratory Studies
- More soil properties and more detail
- Interactions between soil properties

Field Studies
- Field manipulation of soil properties
- Long Term Ecological Studies
- Before After Control Impact studies

Method Development
- More accurate, less time consuming & laborious tasks
- Development and use of new technology
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  Reason for changing atmospheric concentrations UNKNOWN

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......How do soil properties effect this sink?
How can these results be used?

- Improved understanding of climate & fire effects
- Better estimate Australian and global methane flux budgets leading to better management strategies
- Predict the effect of fire and climate change on CH$_4$ oxidation so we can understand the importance and determine if action is required
Questions I aim to answer

Thankyou