CO$_2$ fluxes following cultivation and pasture renewal
– toward increasing carbon storage in pastoral soils –

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Goal

To determine the effect of climate variability and management practices on CO$_2$ and C balance of dairy pastures with the aim to increase soil C gains or decrease losses.
Scope of presentation

• CO₂ balance following cultivation of permanent pasture
• 4-year carbon balance Scott Farm (including cultivation)
• Update ongoing experiment: CO₂ fluxes before and after regrassing to a mixed sward
• Calculating NECB for a farm: use of footprint information
Field site Scott Farm (cultivation and 4 yr NECB)

- DairyNZ research farm
- Intensively managed:
  - Year-round rotational grazing
  - Supplementary feed
- EC measurements from Dec 2007 – Feb 2012
Why C losses following cultivation of permanent pasture?

- Occasional cultivation of permanent pasture is fairly common (part of regrassing or when sowing crops)
- Little research done on effect on SOC storage
- Pastoral soils are generally high in soil C – so could potentially lose much C
C losses (as CO$_2$) following cultivation

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Season</th>
<th># soils</th>
<th>Soil condition</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Late summer/Autumn 2008</td>
<td>1</td>
<td>drought</td>
<td>chamber</td>
</tr>
<tr>
<td>2</td>
<td>Spring 2008</td>
<td>2</td>
<td>normal moisture</td>
<td>chamber</td>
</tr>
<tr>
<td>3</td>
<td>Late summer/Autumn 2010</td>
<td>1</td>
<td>dry</td>
<td>EC</td>
</tr>
</tbody>
</table>

- Losses measured over ~40 days and compared to uncultivated control.

Net effect = NEE$_{\text{cultivated}}$ – NEE$_{\text{uncultivated pasture}}$

Chamber measurements made by then-MSc students Paul Mudge (Exp 1) and Dirk Wallace (Exp 2).
C losses (as CO$_2$) following cultivation controlled by soil moisture

Cultivation under moist conditions led to larger losses

* = Net effect = NEE$_{cultivated}$ − NEE$_{uncultivated}$ pasture

Rutledge, S et al. CO$_2$ emissions following cultivation of a temperate permanent pasture, in prep for submission to AEE
Recovery after cultivation – CO$_2$ flux

Site still a sink for CO$_2$ on the annual timescale despite cultivation

Rutledge, S et al. CO$_2$ and carbon balance of an intensively grazed temperate dairy pasture over four years: responses to weather variations and management practices, in prep
Carbon balance

\[ \text{Carbon balance} = \text{CO}_2 \text{ exchange} + C_{\text{feed}} + C_{\text{effluent}} - C_{\text{milk}} - C_{\text{silage}} - C_{\text{CH}_4} - C_{\text{leaching}} - C_{\text{erosion}} \]

\( \approx \text{change in soil C storage} \)
Over four years, net soil carbon storage increased (despite a severe drought in 2008 and cultivation in 2010).

Management practices had a large impact on the change in C storage (e.g. effluent addition in 2010 and silage cutting in 2011).

Rutledge, S et al. CO₂ and carbon balance of an intensively grazed temperate dairy pasture over four years: responses to weather variations and management practices, in prep.
Can a high diversity sward increase soil C?
– triple site comparison Troughton Farm –

**Hypothesis:**

High diversity sward has more and deeper roots

→ more C input

→ more C storage?
Leading Partners in Science
**Troughton before regrassing**

Preliminary results:

- Pre-regrassing fluxes from three sites are similar
- Grazing events are easily picked up
Preliminary results

Losses following spraying, grazing and direct drilling

Decrease in daytime uptake (drought)

New swards establishing

Soil respiration increases in response to rain

Pasture growth resumes in response to rain

C loss

C gain
NECB on the farm: Use of footprint model

Firstly, to check the extent of the CO$_2$ flux footprint – are we measuring from the intended area?

NECB on the farm: Use of footprint model (con’d)

- Paddocks in the footprint don’t contribute evenly to the measured CO$_2$ fluxes
NECB on the farm: Use of footprint model (con’d)

- Management of individual paddocks in the footprint can differ (a bit)

  → inputs/outputs (kg C/ha) differ between paddocks

\[
\text{NECB} = \text{CO}_2 \text{ exchange} + C_{\text{feed}} + C_{\text{manure}} - C_{\text{milk}} - C_{\text{silage}} - C_{\text{CH}_4} - C_{\text{leaching}}
\]
NECB on the farm: Use of footprint model (con’d)

To just take a straight average of the non-CO$_2$ C fluxes (feed, manure and silage) wouldn’t be right.

Need to match footprints between CO$_2$ and non-CO$_2$ C fluxes

→ weight the non-CO$_2$ C fluxes from the paddocks in the footprint by the contribution of that paddock to the CO$_2$ flux

$$\text{NECB} = \text{CO}_2 \text{ exchange} + C_{\text{feed}} + C_{\text{manure}} - C_{\text{milk}} - C_{\text{silage}} - C_{\text{CH}_4} - C_{\text{leaching}}$$
Conclusions

• Over 4 years soil carbon storage at the Scott Farm site increased, despite large disturbances of drought and cultivation

• Management decisions can have a large effect on the carbon balance

• Cultivation
  • ~80 - 400 g C/m² loss
  • moist conditions led to larger losses
  • Site recovered – no SOC lost (annual timescale)

• Modelling required to get the full picture

• High diversity sward work off to good start
Acknowledgements

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• Dirk Wallace
• Miko Kirschbaum
• David Whitehead
• Ben Troughton

Funding

• New Zealand Agricultural Greenhouse Gas Research Centre
• University of Waikato
• Dairy NZ
Spare slides
Challenges: lack of energy balance closure
Challenges: underestimation of evaporation?
Challenges:
frequency response correction – CO₂ flux

Challenges:
frequency response correction – LE

![Graph showing the comparison between Moncrieff and Ibrom LE (W/m^2) over the period 03/31 to 04/05 in 2012.](image)

![Graph showing a scatter plot of LE Moncrieff vs LE Ibrom (W/m^2).](image)
Closed path vs. Open path - CO$_2$ flux

But different frequency response correction applied:
- Closed path: Ibrom
- Open path: Moncrieff
Closed path vs. Open path - LE

But different frequency response correction applied:
- Closed path: Ibrom
- Open path: Moncrieff
# C losses (as CO$_2$) following cultivation

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*Net effect = NEE$_\text{cultivated}$ – NEE$_\text{uncultivated pasture}$

~2 - 3% of C stored in top 30 cm

Rutledge, S et al. CO$_2$ emissions following cultivation of a temperate permanent pasture, in prep for submission to Agriculture, Ecosystems & Environment.
EC on the farm: fluxes during grazing