CO_2 fluxes following cultivation and pasture renewal

– toward increasing carbon storage in pastoral soils –

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NEW ZEALAND AGRICULTURAL GREENHOUSE GAS Research Centre

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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

- CO_2 balance following cultivation of permanent pasture
- 4-year carbon balance Scott Farm (including cultivation)
- Update ongoing experiment: CO_2 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

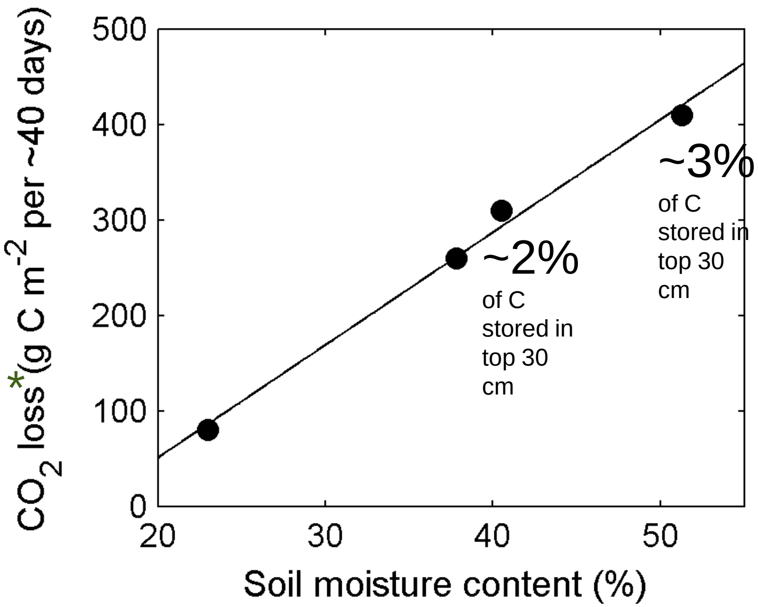
Experiment	Season	# soils	Soil condition	Method
1	Late summer/ Autumn 2008	1	drought	chamber
2	Spring 2008	2	normal moisture	chamber
3	Late summer/ Autumn 2010	1	dry	EC

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

Net effect = $NEE_{cultivated} - NEE_{uncultivated\ pasture}$

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

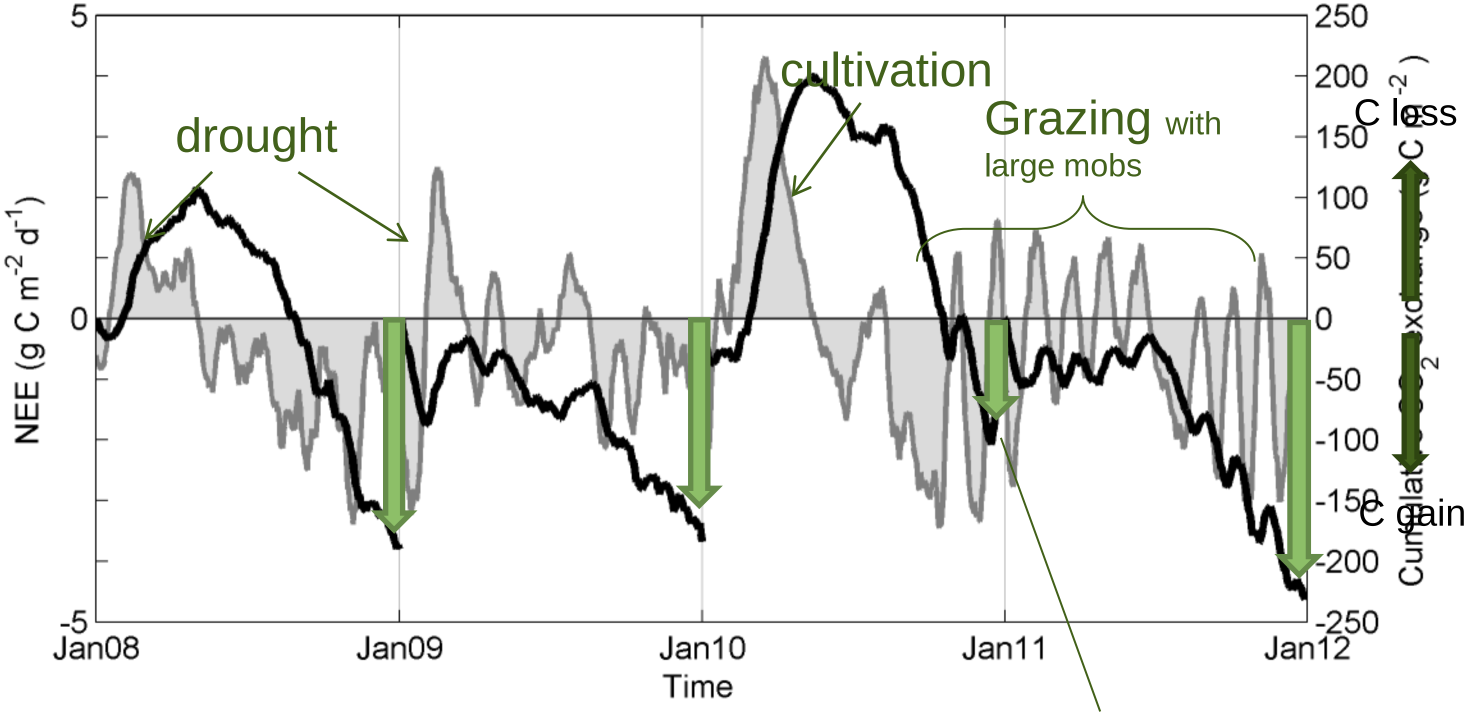


- Cultivation under moist conditions led to larger losses

* = 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

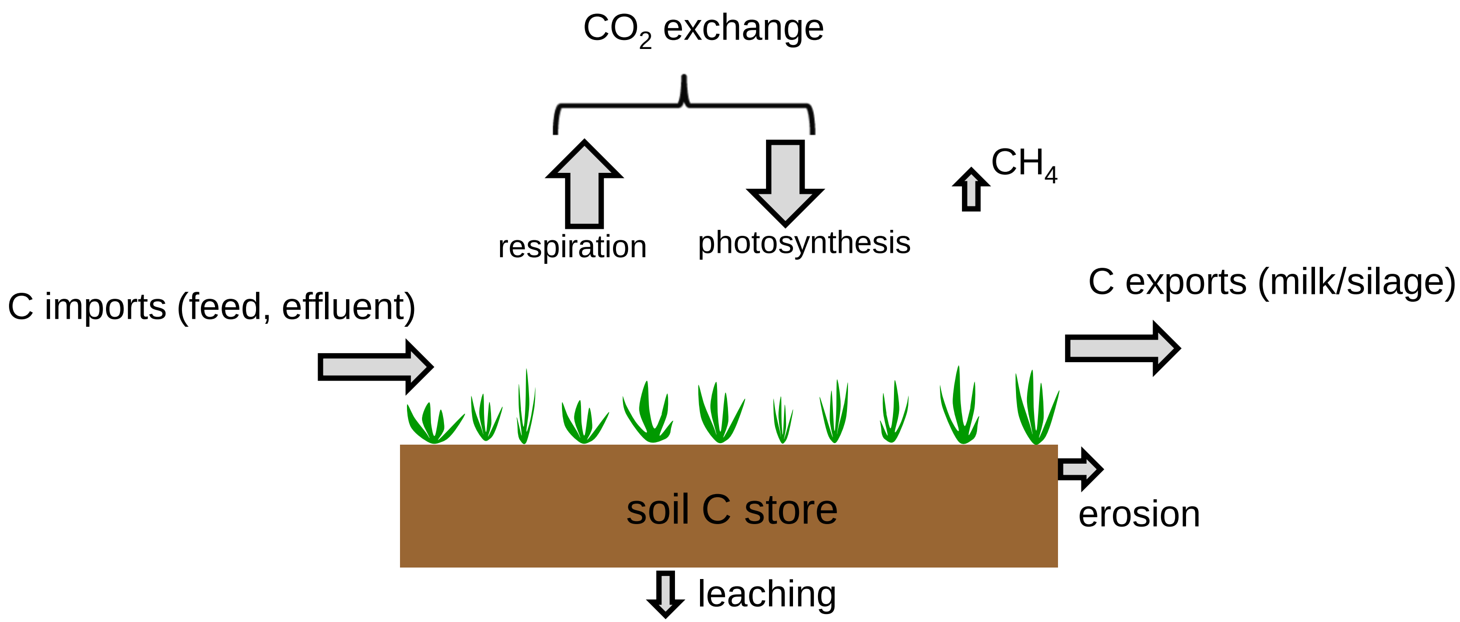
Recovery after cultivation – CO_2 flux



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

C budget – Net Ecosystem Carbon Balance

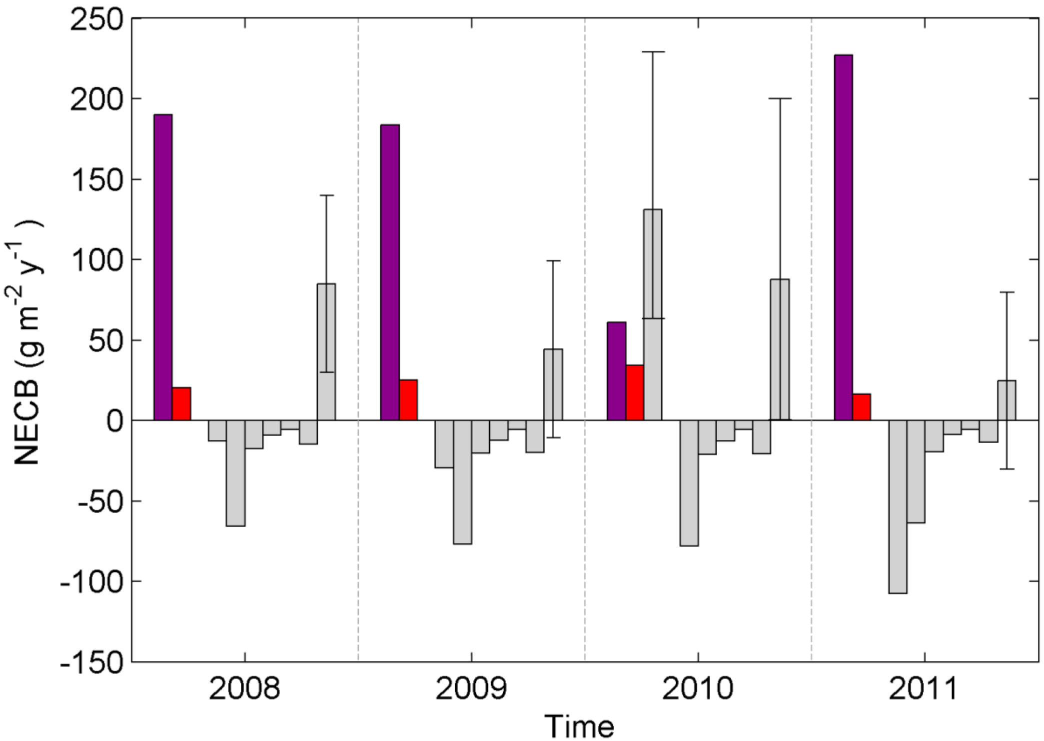


Carbon balance

$$= CO_2 \text{ exchange} + C_{feed} + C_{effluent} - C_{milk} - C_{silage} - C_{CH4} - C_{leaching} - C_{erosion}$$

$\approx$ **change in soil C storage**

Recovery after cultivation – C balance



- Over four years, net soil carbon storage increased (de… ought in 2… on in 201…
- Ma… es had… the cha… e.g. eff… 010 and silage cutting in 2011)

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

Can a high diversity sward increase soil C ?

– triple site comparison Troughton Farm –

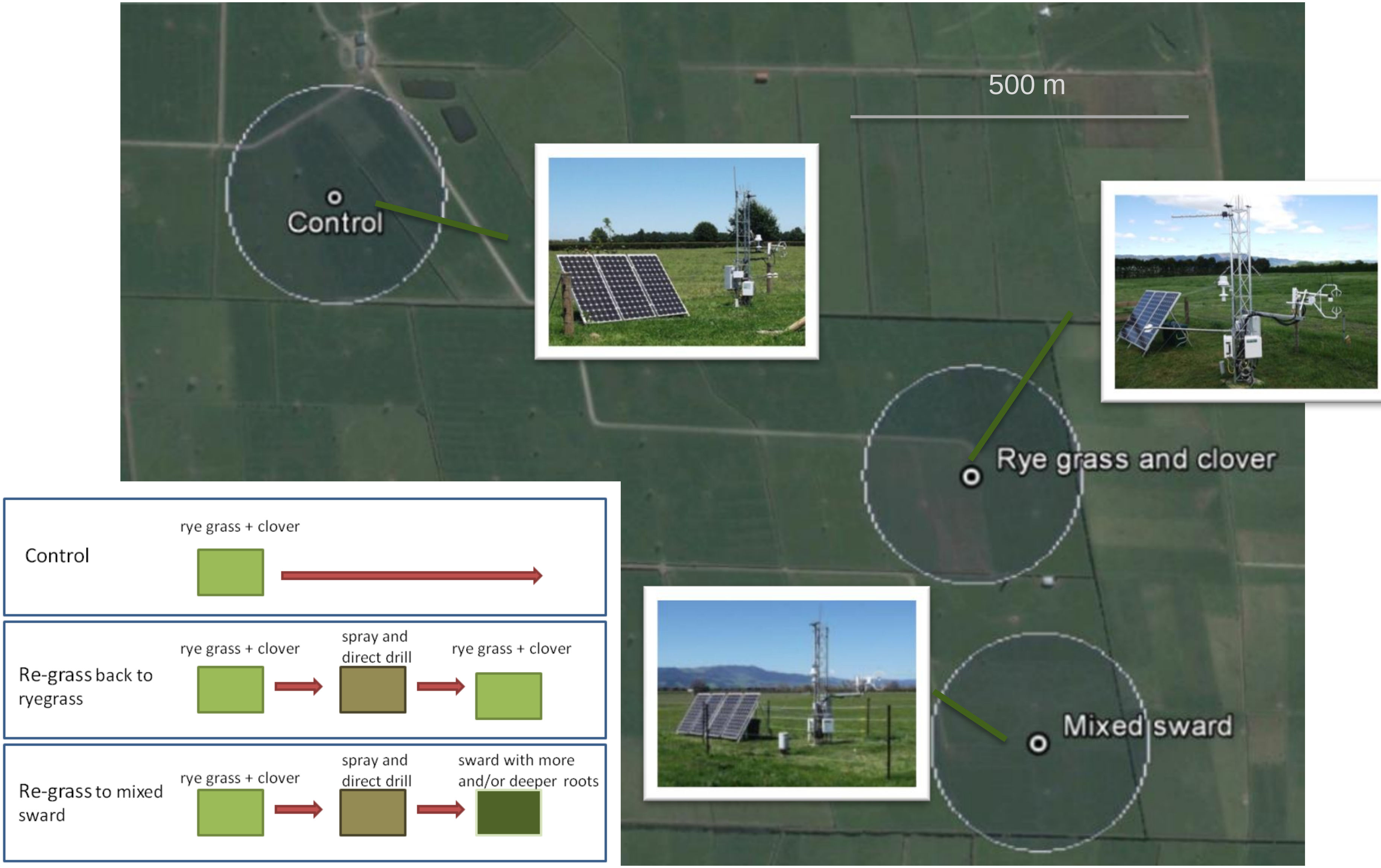
Hypothesis:

High diversity sward has more
and deeper roots

→ more C input

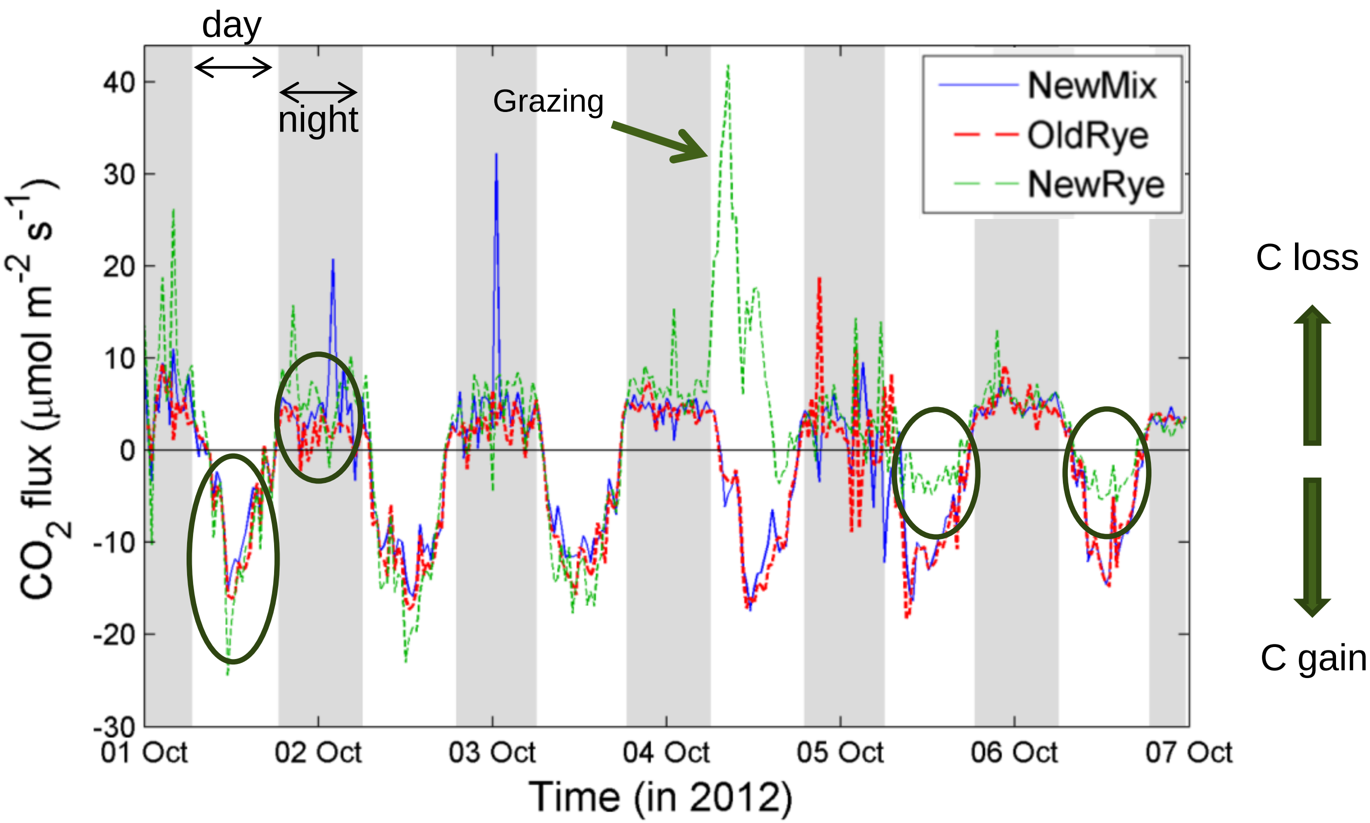
→ more C storage?

vs.



500 m
Control
Rye grass and clover
Mixed sward
Control
rye grass + clover
Re-grass back to ryegrass
rye grass + clover
spray and direct drill
rye grass + clover
Re-grass to mixed sward
rye grass + clover
spray and direct drill
sward with more and/or deeper roots

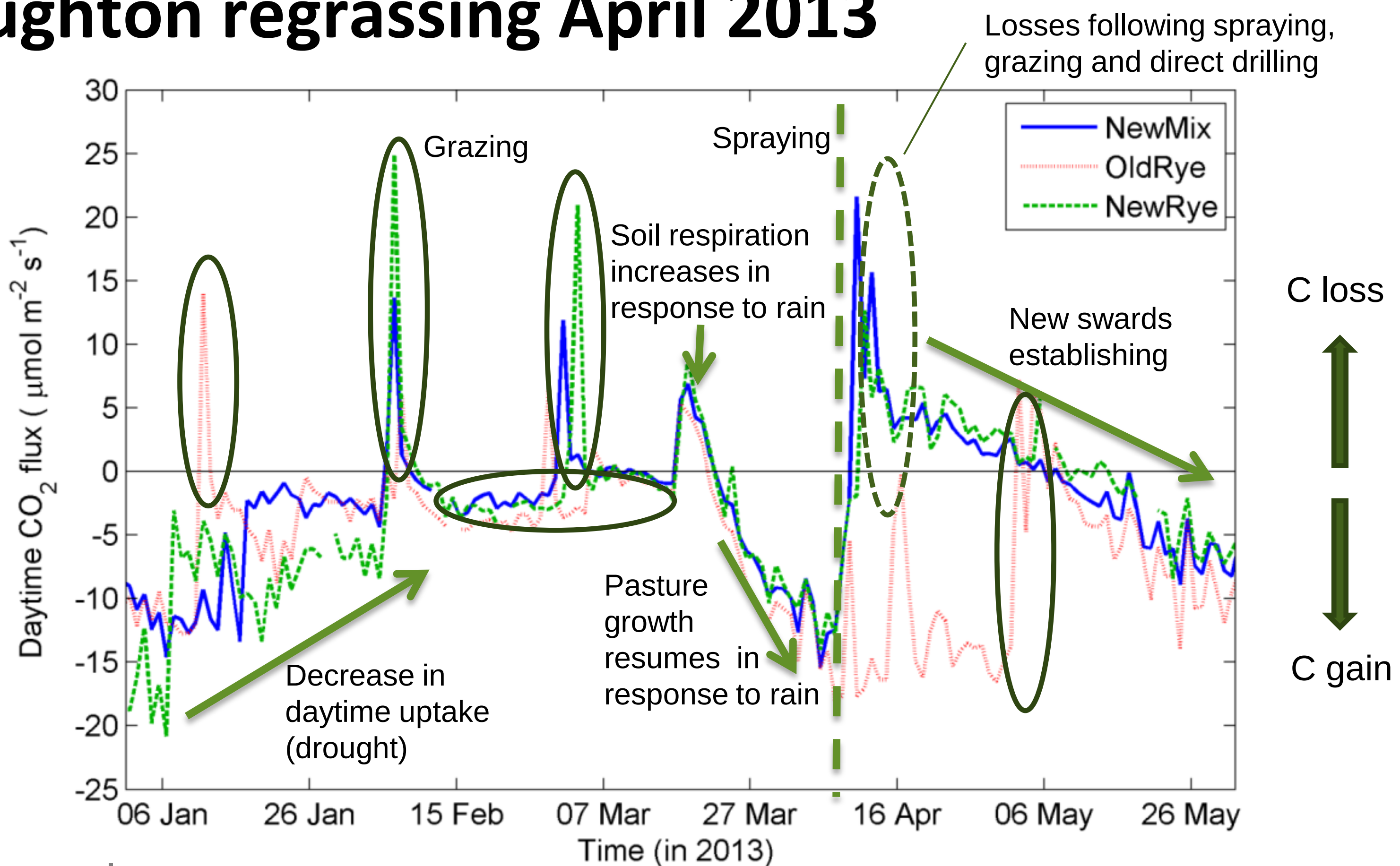
Troughton before regrassing



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

Preliminary results

Troughton regrassing April 2013

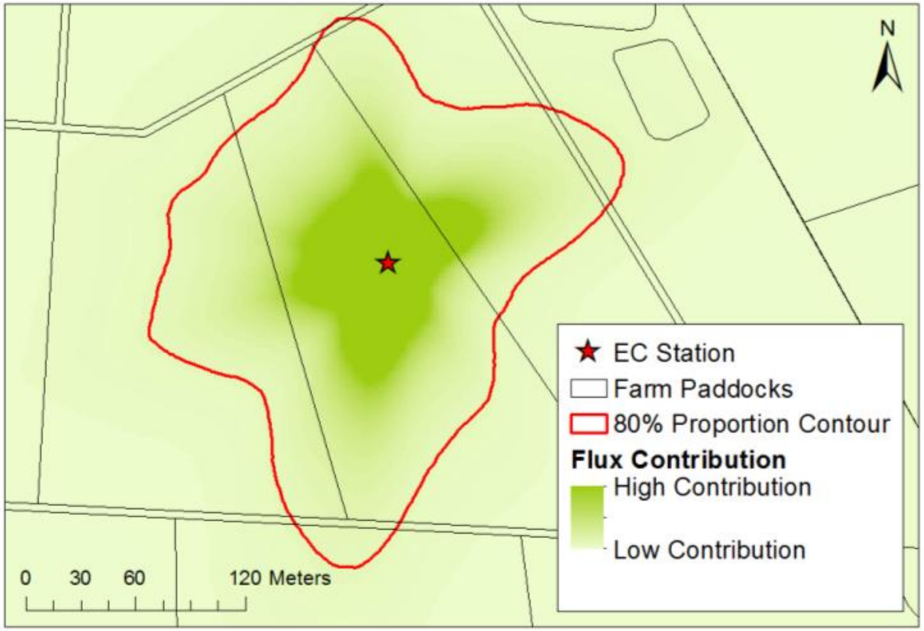


Preliminary results

NECB on the farm: Use of footprint model

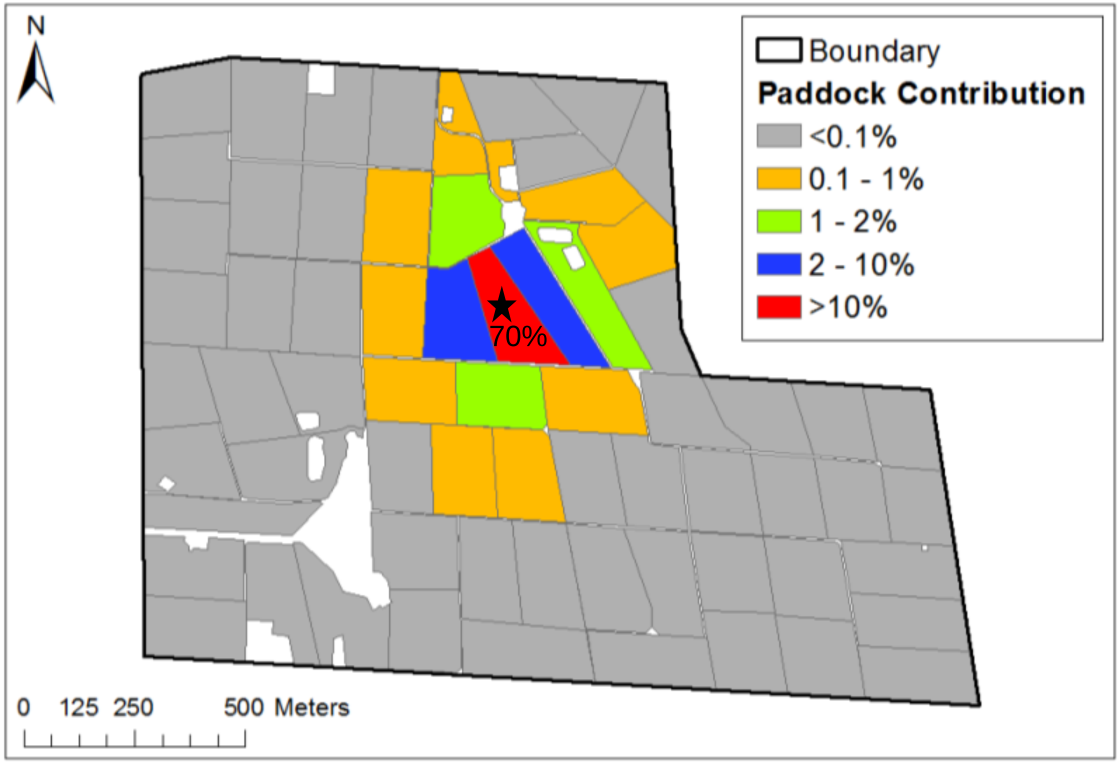
Firstly, to check the extent of the CO_2 flux footprint

– are we measuring from the intended area?



Kormann, R., Meixner, F.X., 2001. An analytical footprint model for non-neutral stratification. BLM 99, 207-224

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



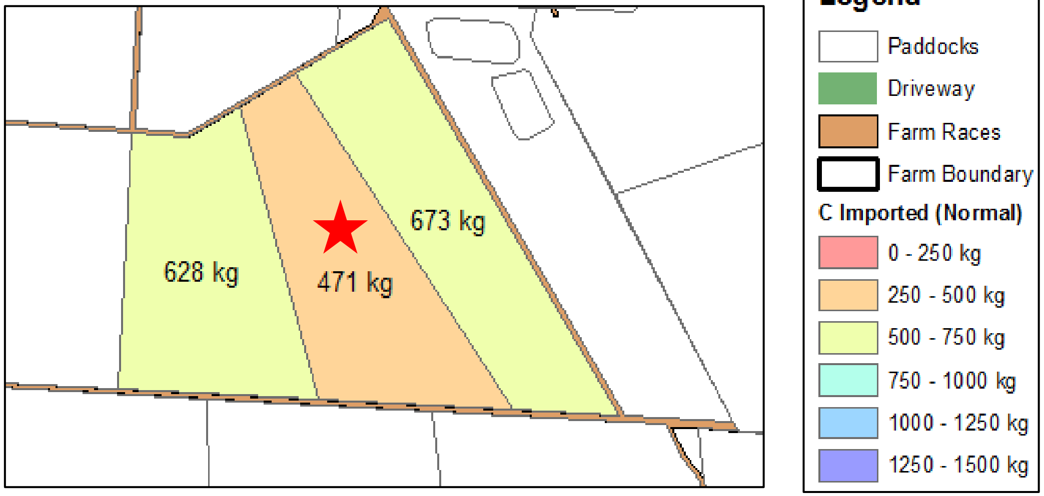
- Paddocks in the footprint don't contribute evenly to the measured CO_2 fluxes

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

e.g. C in imported feed



$$NECB = CO_2 \text{ exchange} + C_{feed} + C_{manure} - C_{milk} - C_{silage} - C_{CH4} - C_{leaching}$$

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

$$\text{NECB} = CO_2 \text{ exchange} + C_{feed} + C_{manure} - C_{milk} - C_{silage} - C_{CH4} - C_{leaching}$$

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/m^{-2} 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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- David Whitehead
- Ben Troughton

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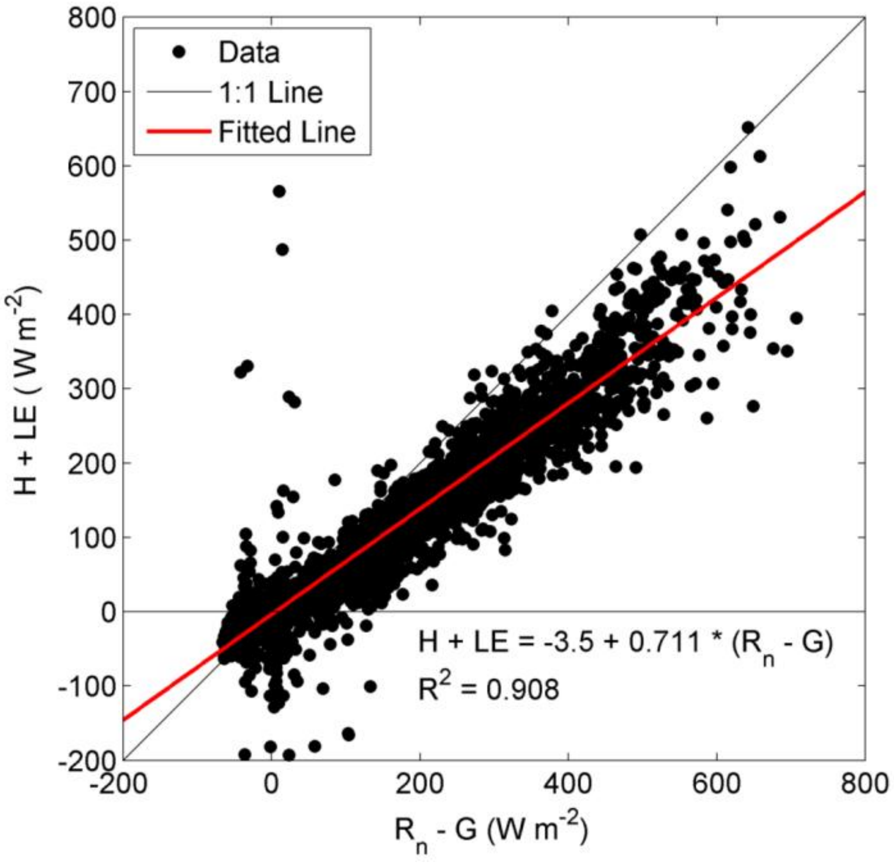
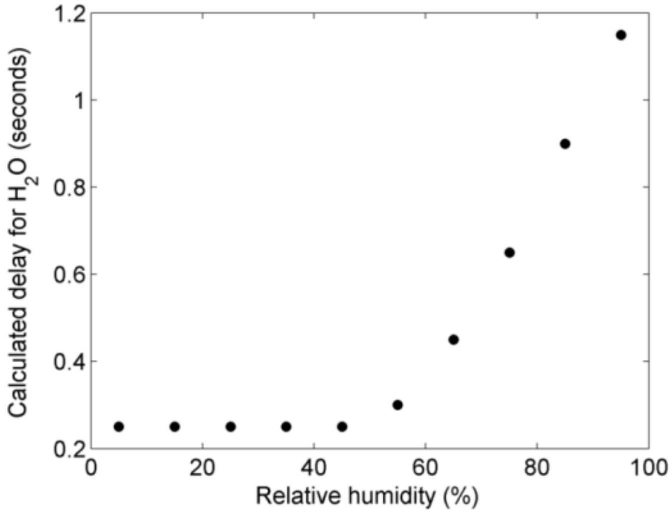
- New Zealand Agricultural Greenhouse Gas Research Centre
- University of Waikato
- Dairy NZ

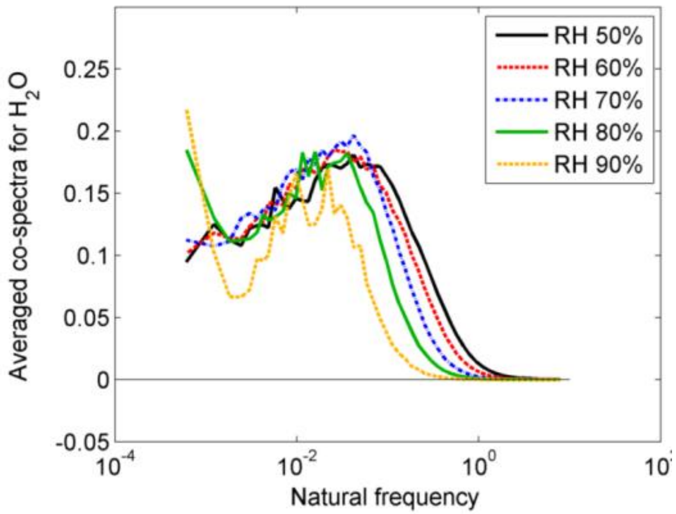
Spare slides

Challenges: lack of energy balance closure

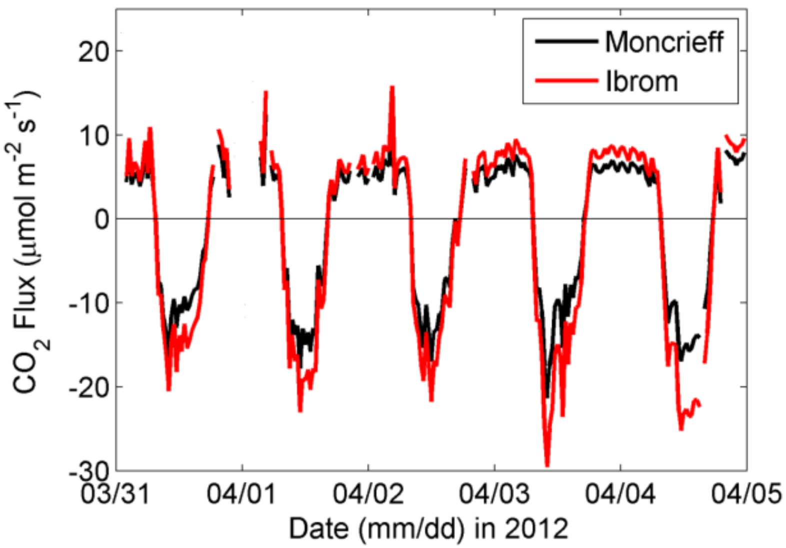


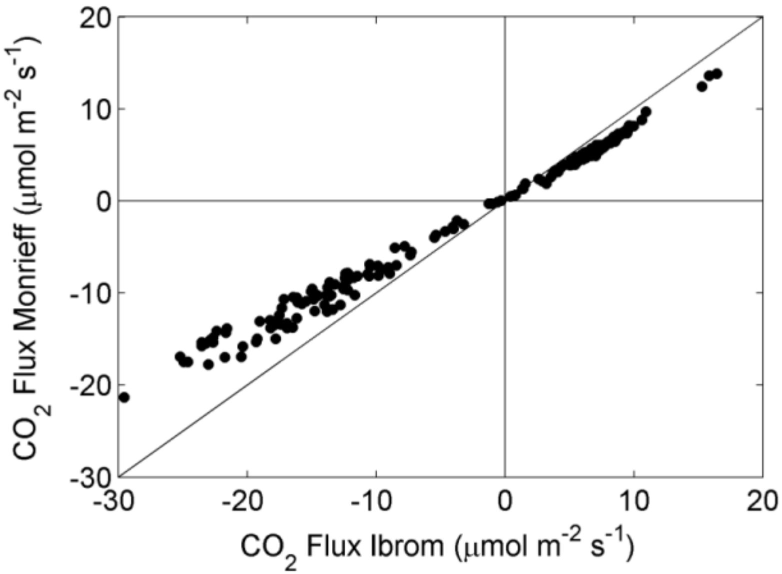
Challenges:
underestimation of evaporation?





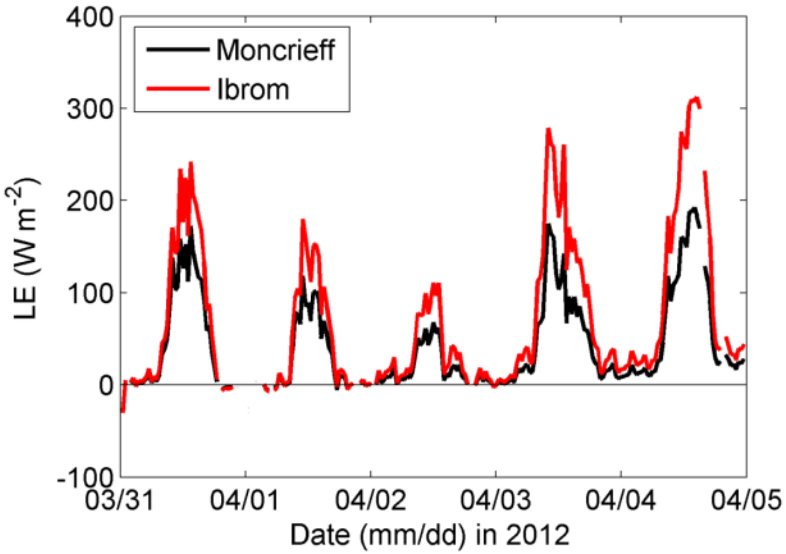
Challenges:
frequency response correction – CO_2 flux

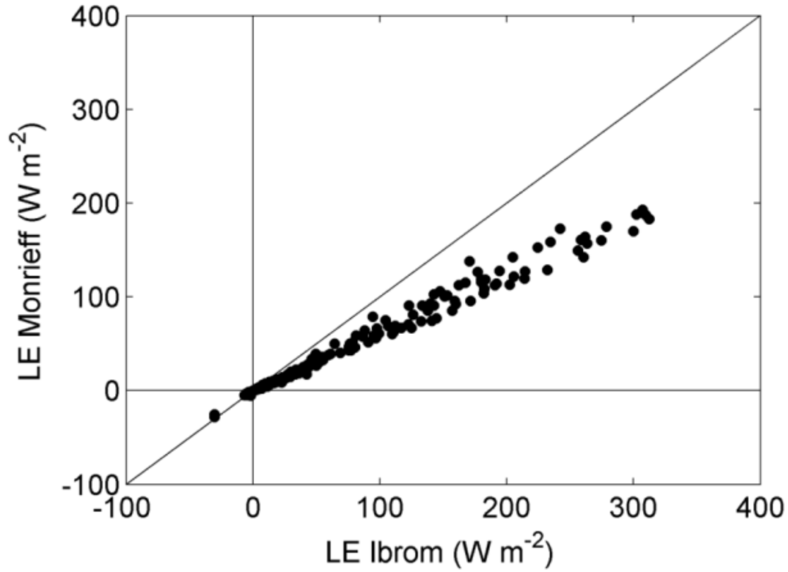




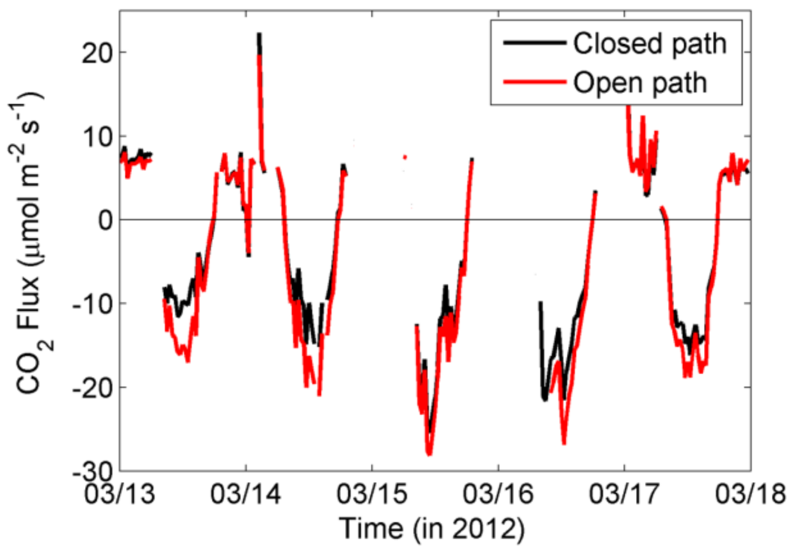
Moncrieff, J. B., et al. 1997. A system to measure surface fluxes of momentum, sensible heat, water vapor and carbon dioxide, Journal of Hydrology, 188-189: 589-611.
Ibrom, A., et al. 2007.Strong low-pass filtering effects on water vapor flux measurements with closed-path eddy correlation systems, Agricultural and Forest Meteorology, 147:140-156.

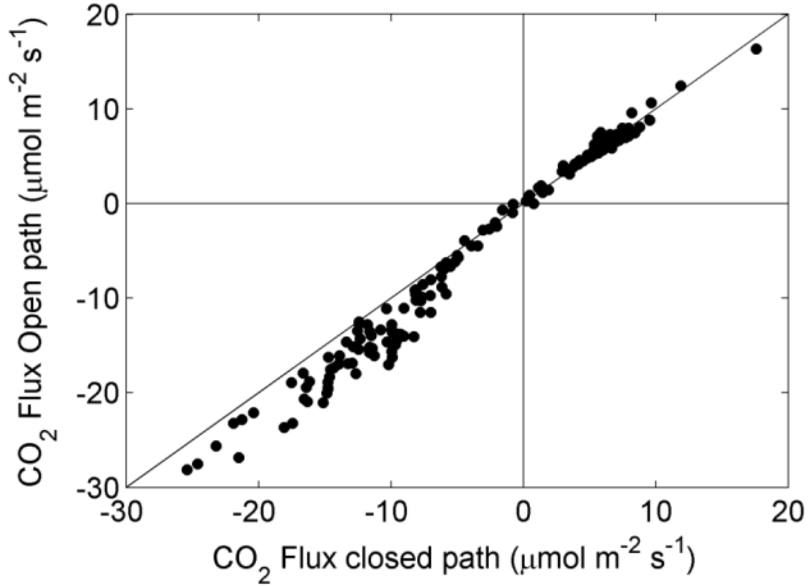
Challenges:
frequency response correction – LE





Closed path vs. Open path - CO_2 flux

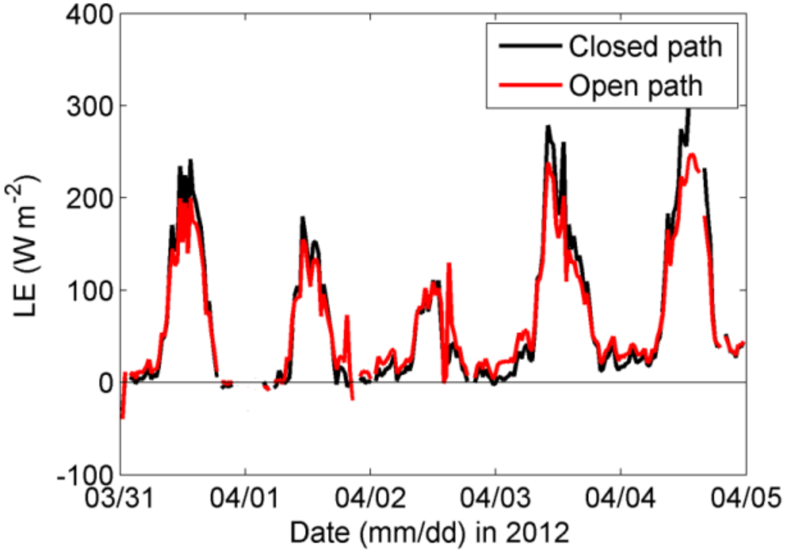


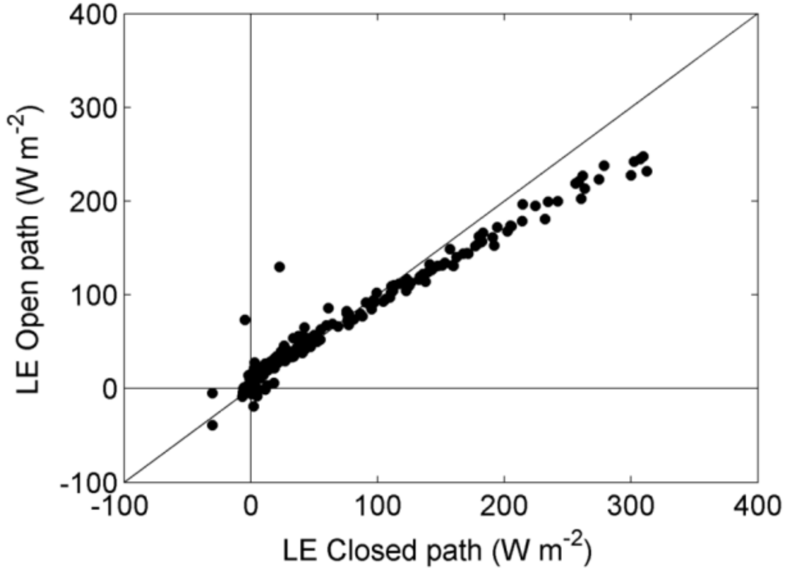


But different frequency response correction applied:

- 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

Experiment	Season	# soils	Soil condition	Net effect* over ~ 40 days (g/m^2)
1	Late summer/ Autumn 2008	1	drought	**80**
2	Spring 2008	2	normal moisture	**310 – 410**
3	Late summer/ Autumn 2010	1	dry	**260**

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

*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 Agriculture, Ecosystems & Environment.

EC on the farm: fluxes during grazing