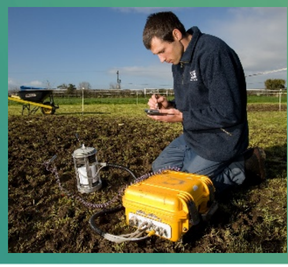
CO_2 and water dynamics following pasture renewal to a moderately diverse pasture

Susanna Rutledge, Jack Pronger, Dave Campbell,
Aaron Wall, Paul Mudge, Louis Schipper



WORKING TOGETHER

Objective of soil carbon programme of NZAGRC*

Identify management practices that can increase soil carbon gains or decrease losses in dairy farms

- Introduce deep burrowing earthworms
- Incorporate biochar
- Optimise irrigation
- Decrease frequency or level of cultivation as part of pasture renewal
- Higher diversity pasture with more and deeper roots

* New Zealand Agricultural Greenhouse Gas Research Centre, http://www.nzagrc.org.nz

Scope of presentation

Part 1: Pasture renewal

- CO_2 loss with and without full cultivation

Part 2: Higher diversity pasture

- Water use
- Impact of grazing on CO_2 dynamics
- Annual CO_2 exchange one year before and after pasture renewal

Pasture renewal (PR*)

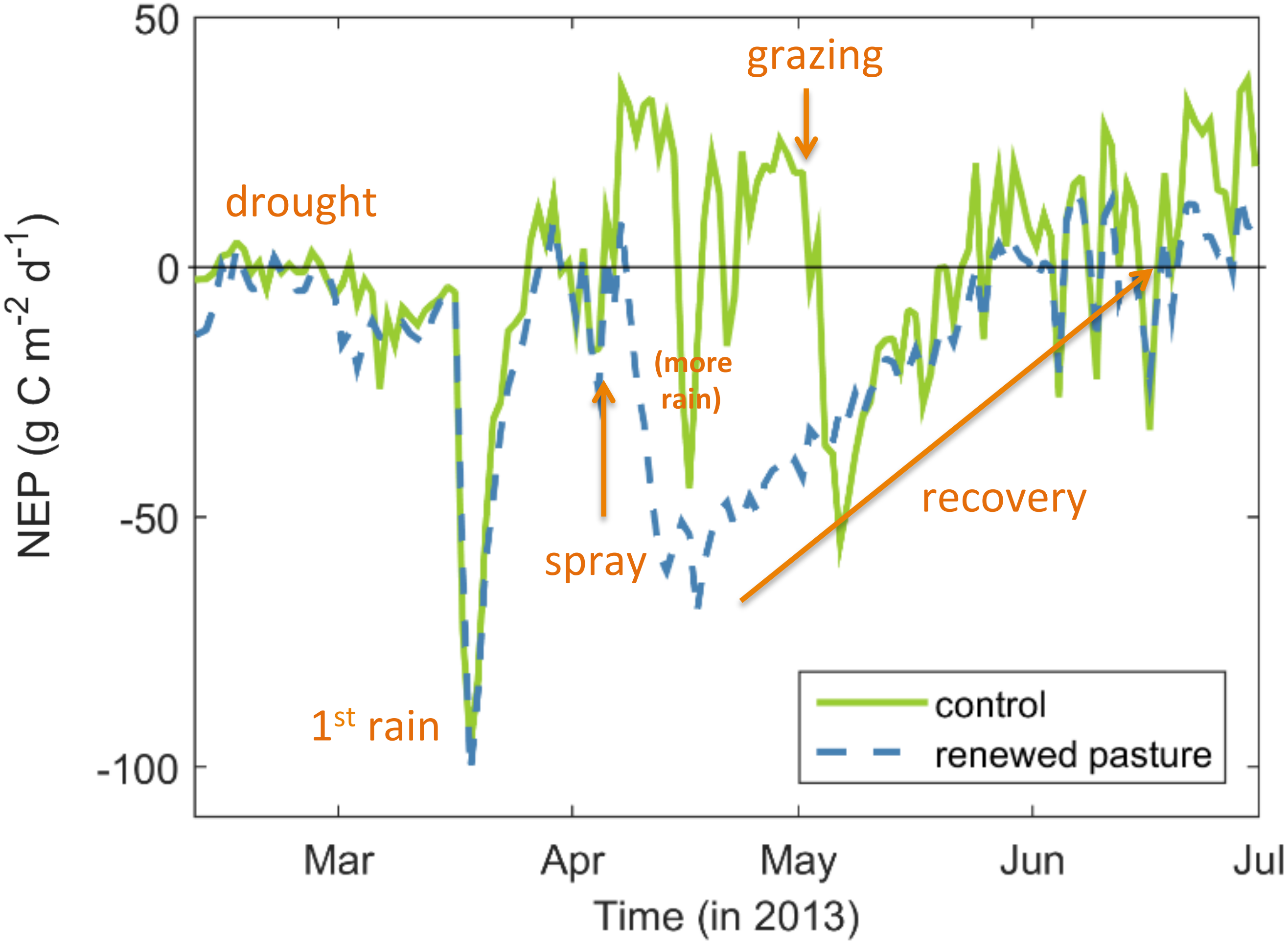
- PR is common on dairy farms (in NZ, ~8% of farm renewed annually)
- Two basic methods:
  - spray + cultivate + sow
  - spray + direct drill
- Little research done on effect of PR on SOC storage
- Pastoral soils are generally high in soil C – so could potentially lose much C

* PR is also referred to as pasture 'restoration' or 'renovation'

Pasture renewal events studied

- Six regrassing events (between 2008-2013 on two farms)
- Different soils, seasons and moisture conditions
- Double spray + cultivation (CULT) vs. single spray and direct drill (DD)
- Eddy covariance and chambers
- Net effect of pasture renewal = net CO_2 exchange$_{renewed}$ – net CO_2 exchange $_{control\ pasture}$

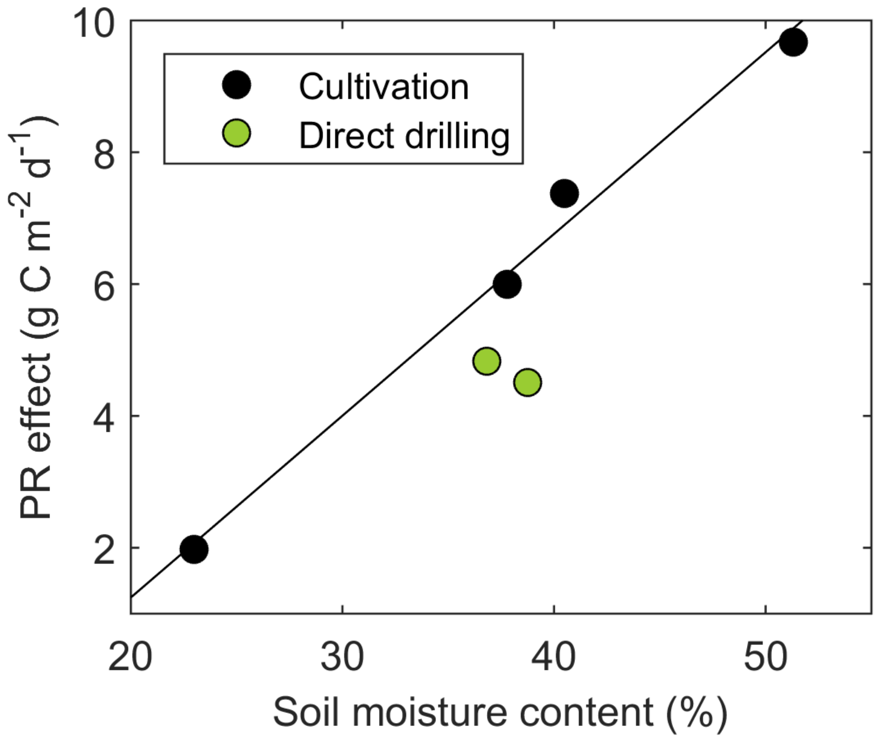
CO_2 exchange during pasture renewal



CO_2 sink

CO_2 source

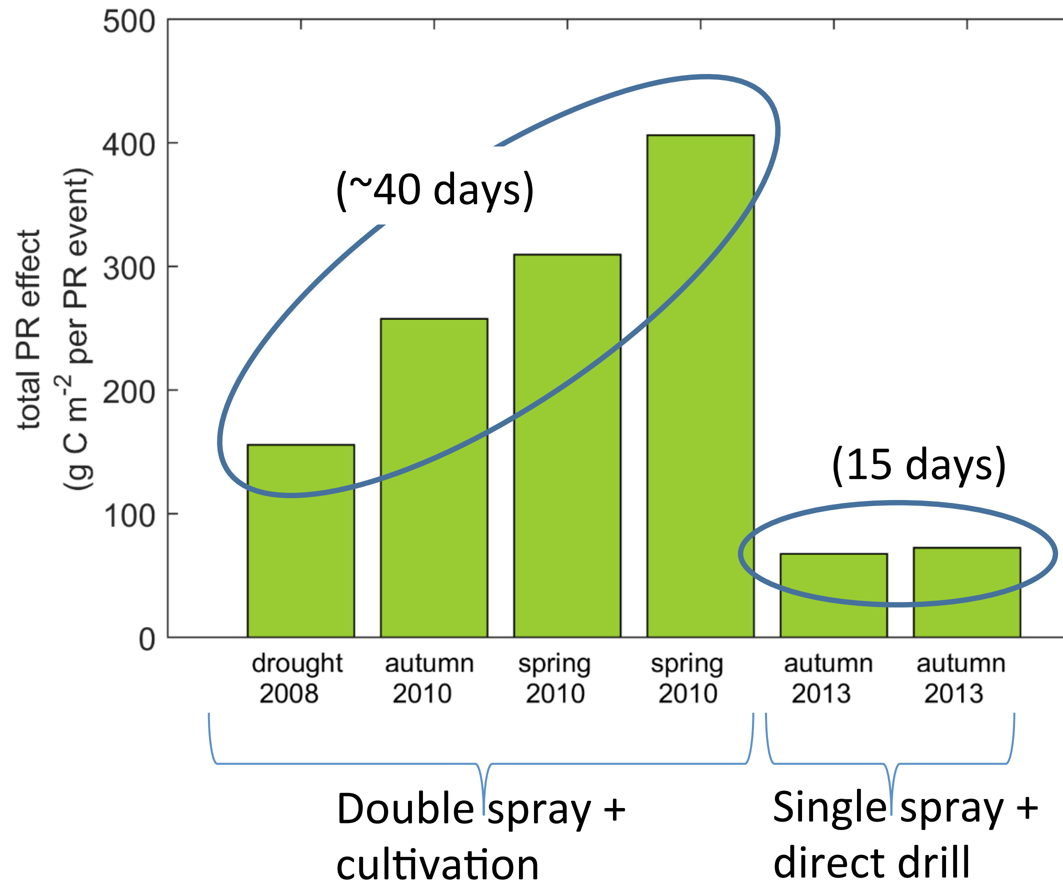
Rate of CO_2 loss due to pasture renewal



- Moisture status of soil was main control on rate of CO_2 loss
- Direct drilling somewhat lower rate of CO_2 loss
- No decrease of rates of CO_2 loss before seedlings emerge

Rutledge, S., Mudge, P.L., Wallace, D.F., Campbell, D.I., Woodward, S.L., Wall, A.M., Schipper, L.A., 2014. CO_2 emissions following cultivation of a temperate permanent pasture. Agriculture, Ecosystems and Environment, 184, 21-33

Impact of pasture renewal duration* on CO_2 loss



- Between 70 and 400 g C ha^{-1} before seedlings emerged
- Combination of moderately dry conditions and short regrassing event
  lowest C losses

* Pasture renewal duration = the time between herbicide spraying of the old pasture and seedling emergence of the new pasture

Conclusions pasture renewal

- Rate of CO_2 loss due to PR largely controlled by moisture status of soil

- Rate of CO_2 loss under direct drilling lower than with full cultivation
  (both lack of C inputs by photosynthesis and physical disturbance important)

- Duration is important – the longer the site is left bare, the higher the CO_2 losses

Recommendations pasture renewal to minimise carbon losses

- regrass under sub-optimal conditions for microbial activity and photosynthesis
 (i.e. late summer/autumn)

- use direct drilling

- minimise time between spraying and sowing

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Pasture species diversity

Low diversity

- ryegrass
- white clover

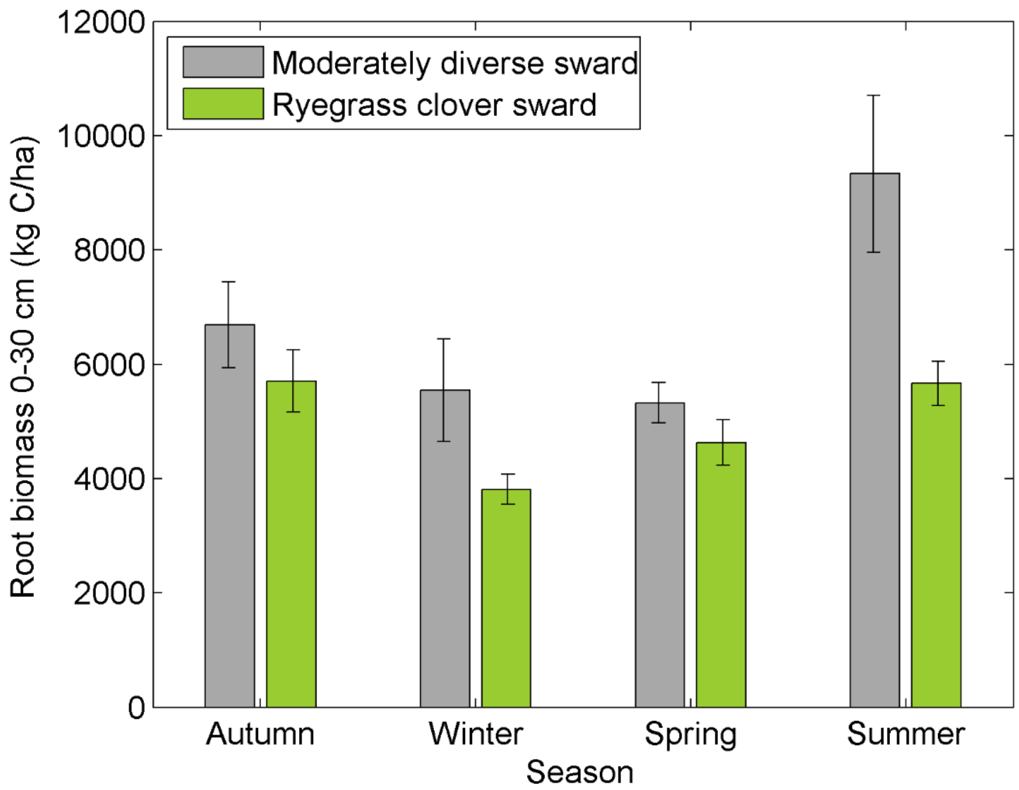
Moderate diversity

- ryegrass, prairie grass, timothy, cocksfoot (grasses)
- multiple clovers, lucerne (legumes)
- chicory, plantain (herbs)

Root biomass of diverse sward

- More roots under more diverse sward, especially deeper down (below 10 cm)

- ~ 1 T C/ha more input (from roots to soil) under the more diverse sward



McNally, S.R., Laughlin, D.C., Rutledge S., Dodd, M.B., Six, J., Schipper., 2015. Root carbon inputs under moderately diverse sward and conventional ryegrass-clover pasture: implications for carbon sequestration. Plant and Soil, 392, 1-2, 289-299

Can a higher diversity sward increase soil C ?

Higher diversity pasture has
more and deeper roots

Hypothesis:

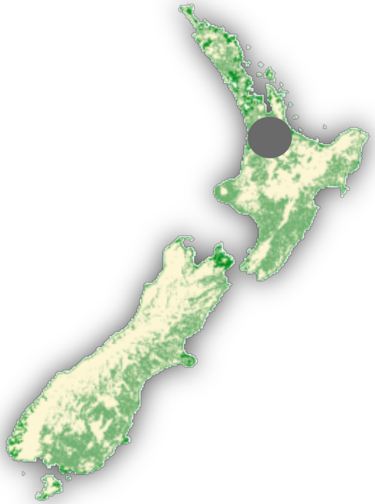
- more C input from roots to soil (especially lower in the soil profile where C saturation deficit is larger)

- more C storage?

Troughton Farm

Warm temperate climate

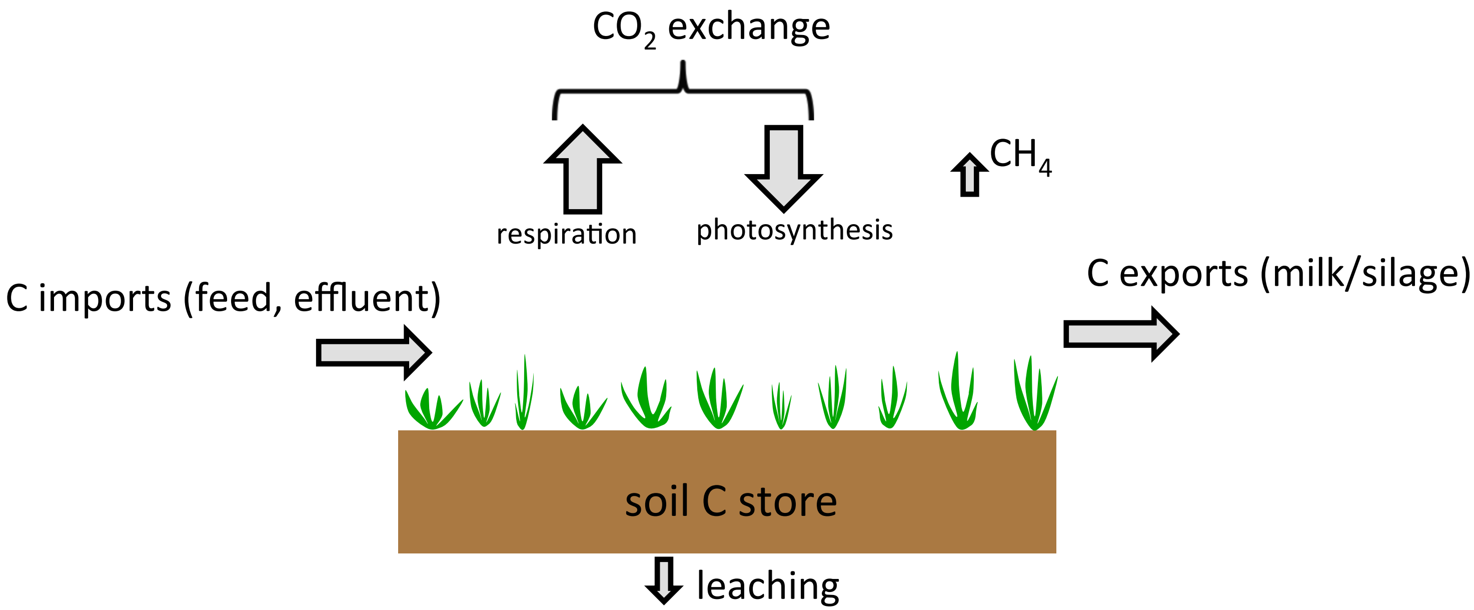
- MAT 13.3°C
- rainfall 1250 mm y^{-1}
- Summer dry period (NZ ‘drought’)



Farm management

- year-round outdoor rotational grazing
- ~150 kg N ha^{-1} y^{-1}
- Supplemental feed

Net ecosystem carbon balance

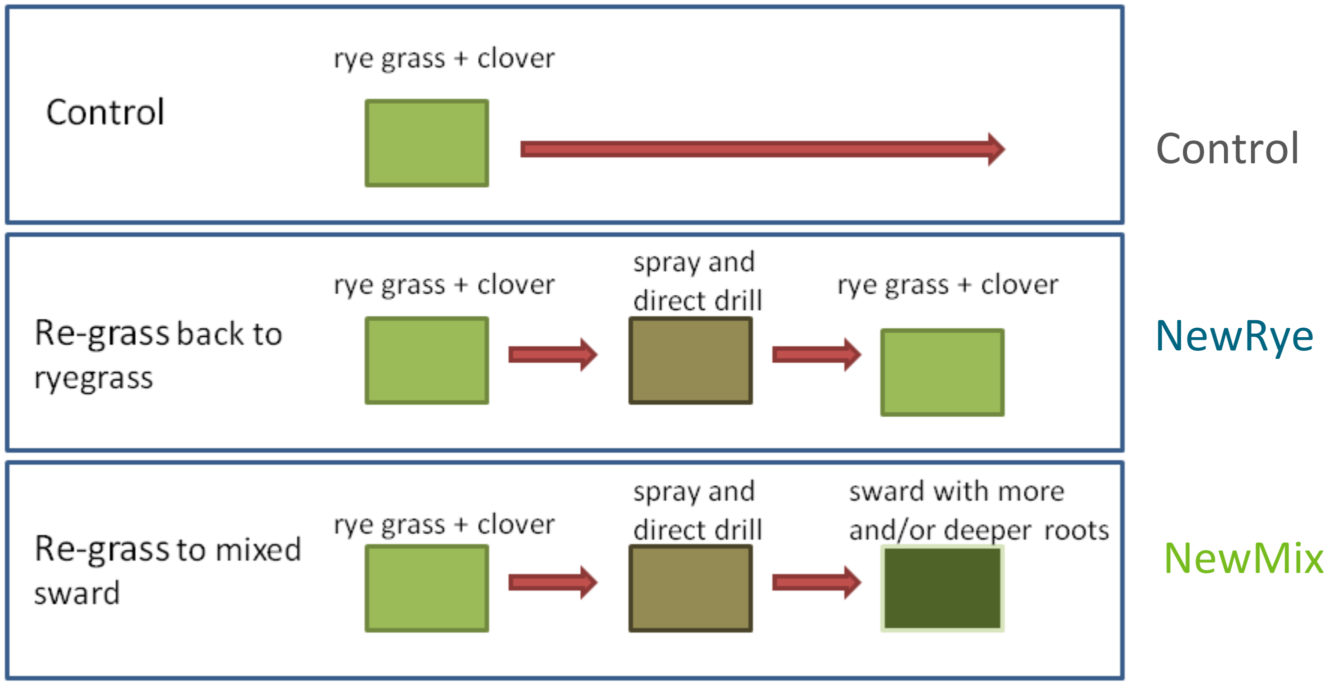


Carbon balance

= C inputs – C outputs

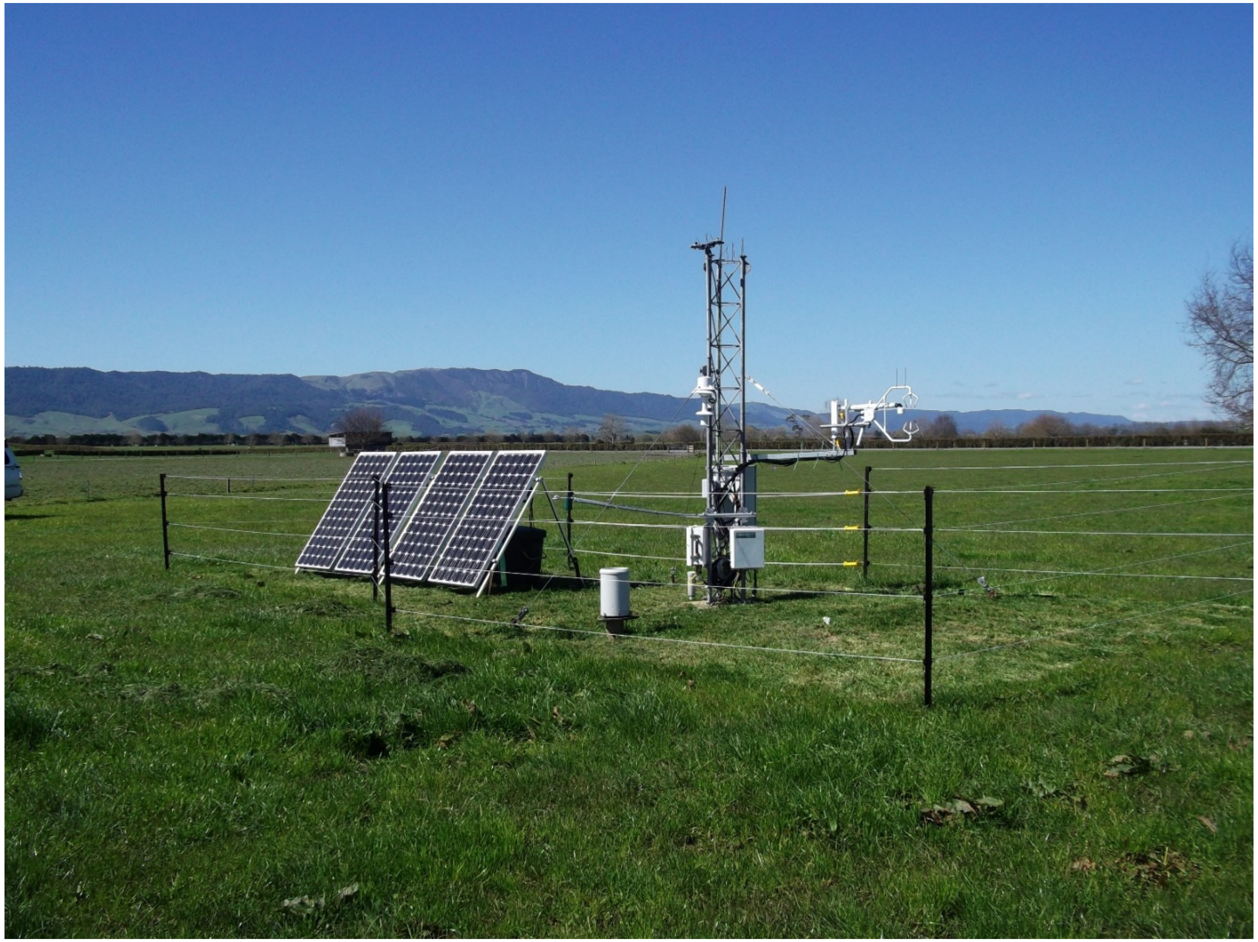
≈ change in soil C storage

Experimental design



500 m
New Rye
Control
NewMix
N
0
100 Km

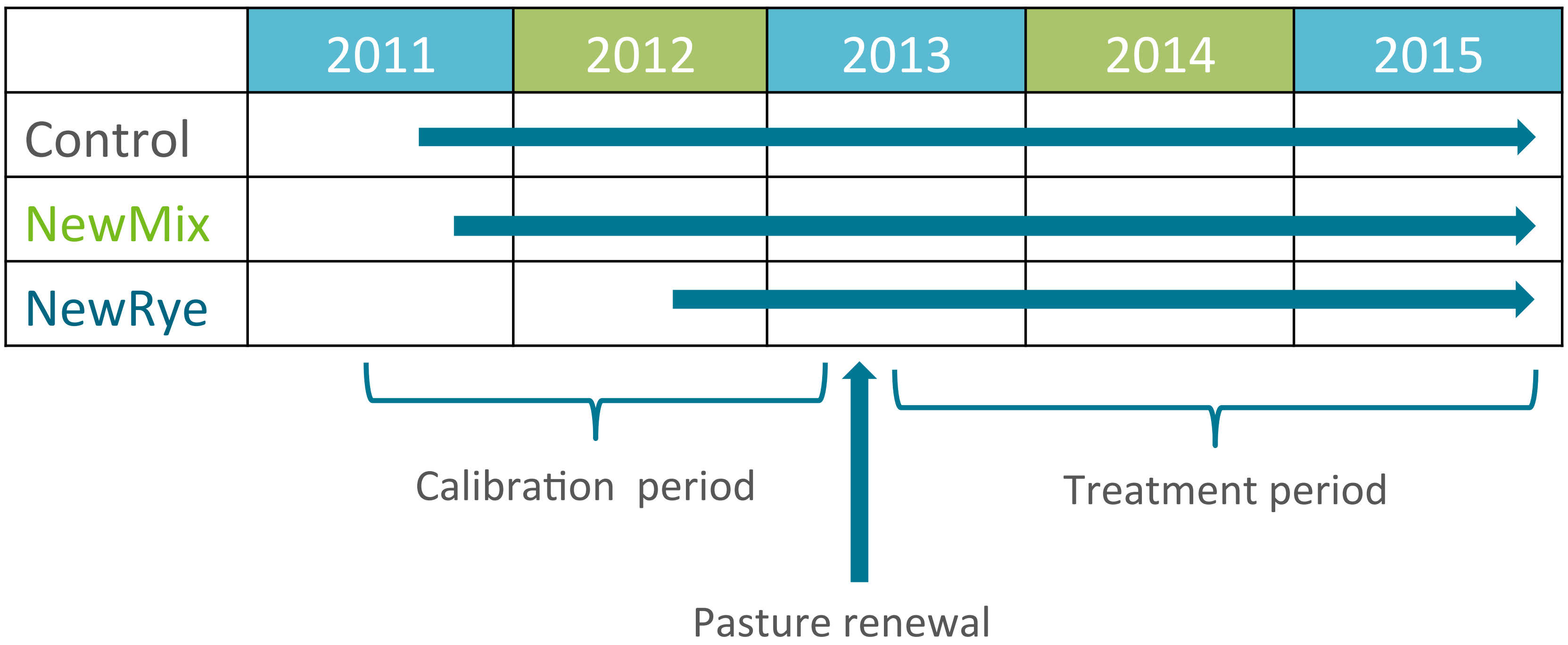
Eddy covariance setup (x3)



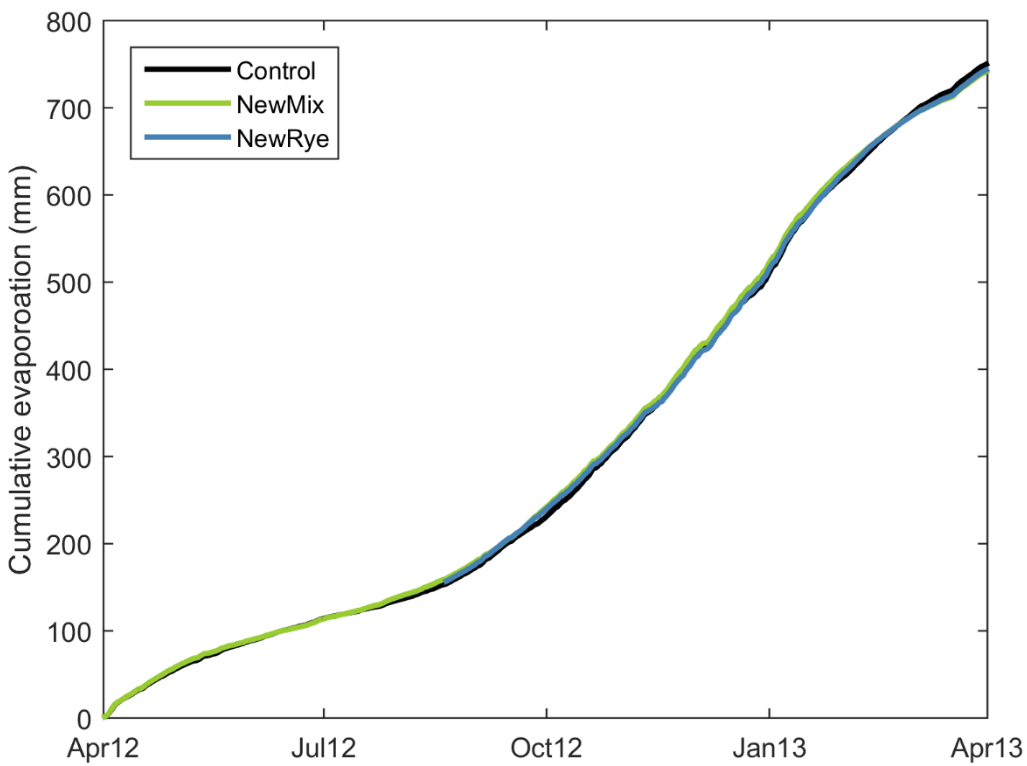
Instruments:

- CSAT3
- LI7200

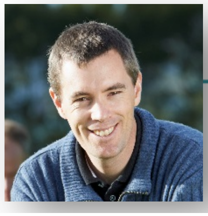
Experiment timeline



Evaporation – main findings so far

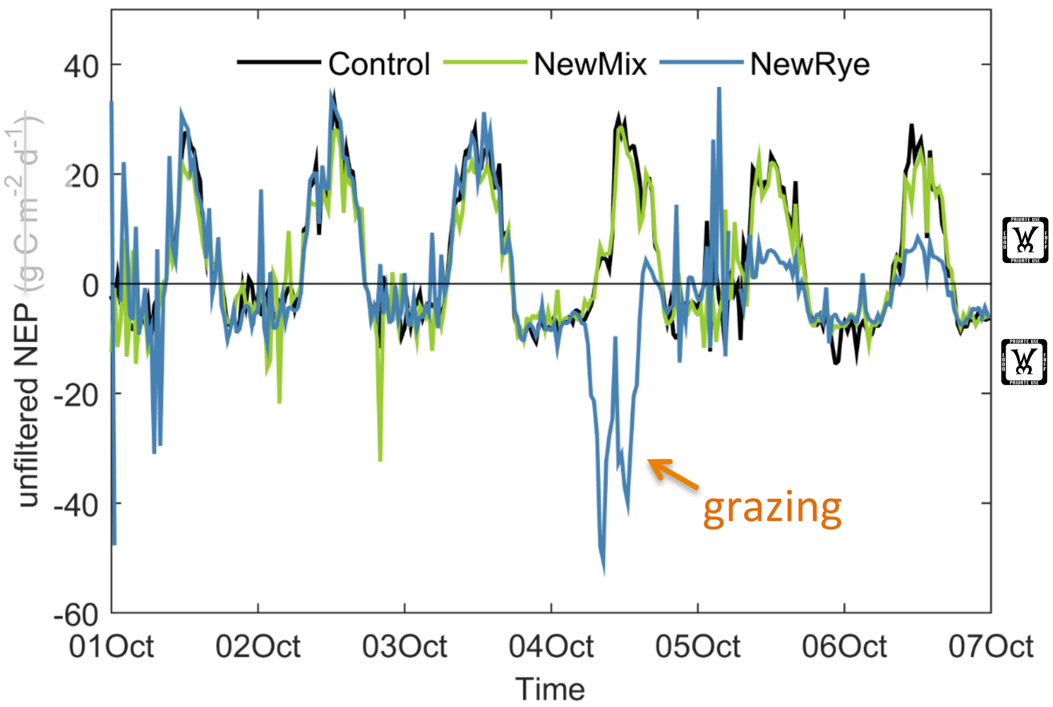


- E driven by radiation and soil moisture
  - Low spatial variability during calibration period
  - Low inter-annual variability of control site over 3 years
- No effect of grazing on E (probably due to soil compensation)



Jack Pronger et al, in prep. Low spatial and inter-annual variability in evaporation from a year round intensively grazed temperate pasture system in New Zealand

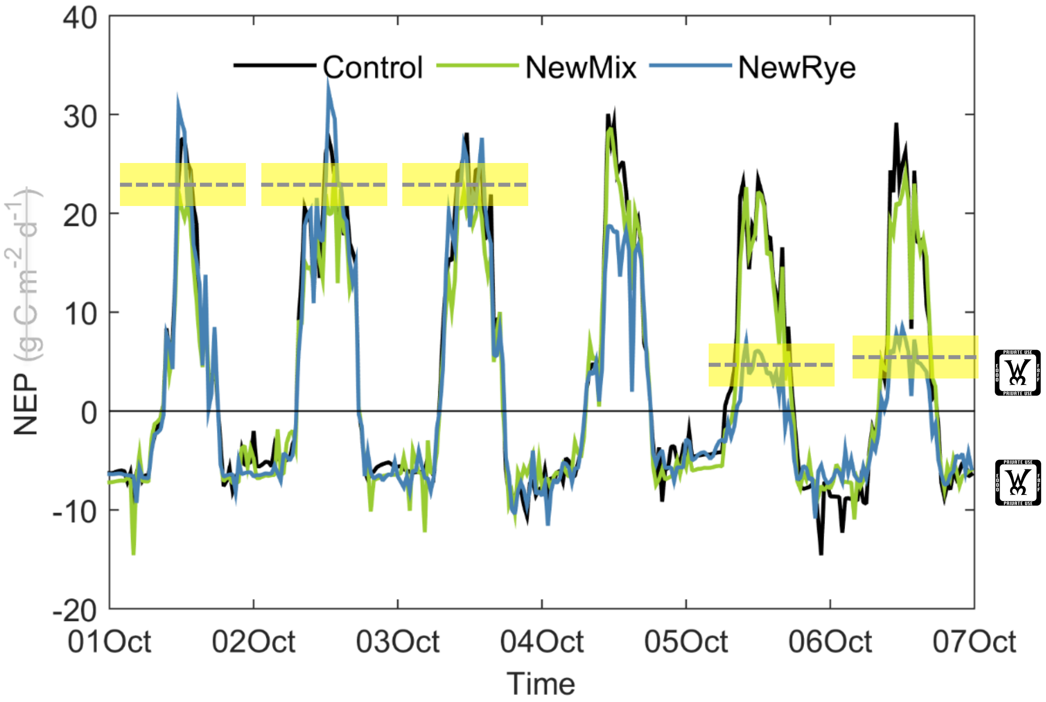
Impact of grazing on CO_2 exchange



sink

source

Impact of grazing on CO_2 exchange



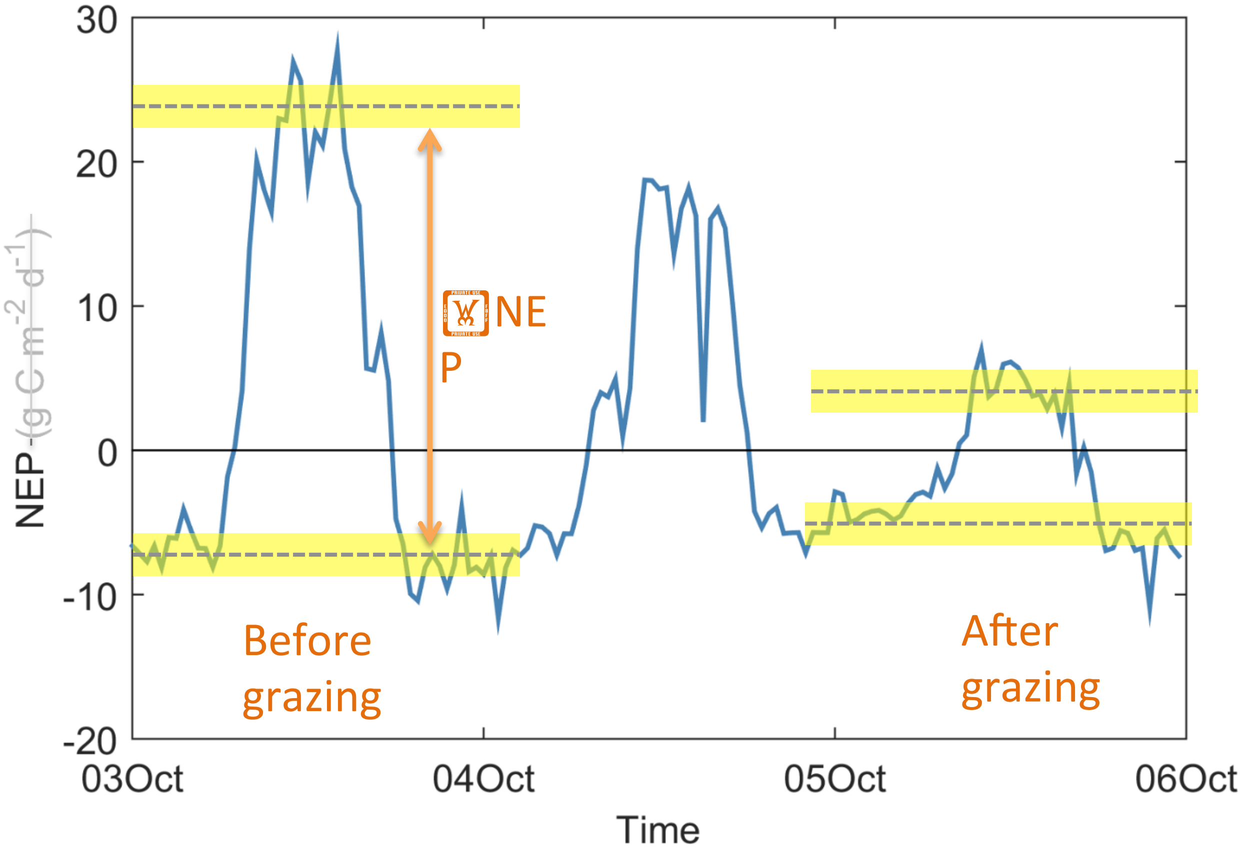
sink

source

How to quantify grazing effect?

- Biomass measurements
- Leaf area index
- Remote sensing (e.g. NDVI)
- Phytomass Index (PI)

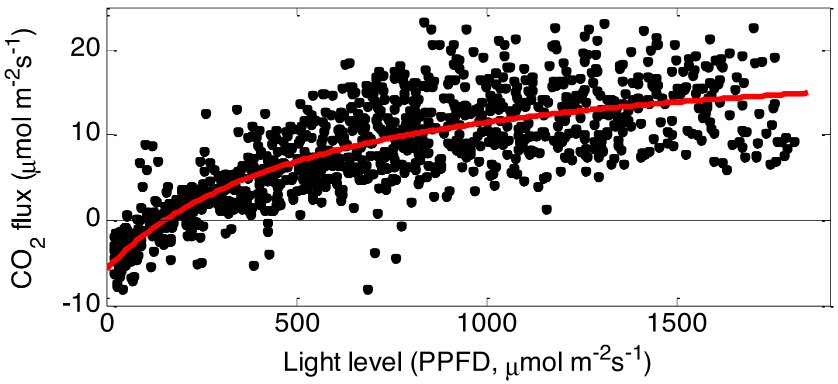
Phytomass index

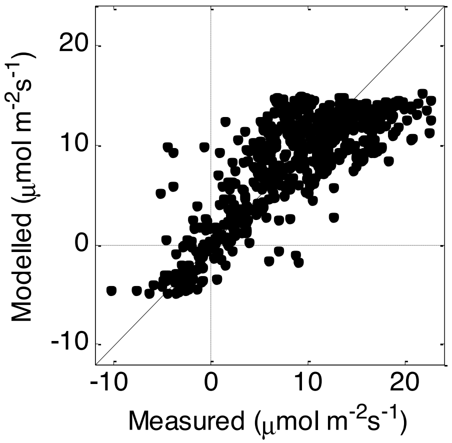


$PI = \Delta NEP_{day-night} / \max(\Delta NEP_{day-night})$

Lohila, A., et al. (2004). Annual CO_2 exchange of a peat field growing spring barley or perennial forage grass. JGR, *109*(D18116)
Campbell, D. I., et al. (2015). Variations in CO_2 exchange for dairy farms with year-round rotational grazing on drained peatlands. Agriculture, Ecosystems & Environment, 202, 68-78.

Light-response of daytime CO_2 exchange – conventional approach





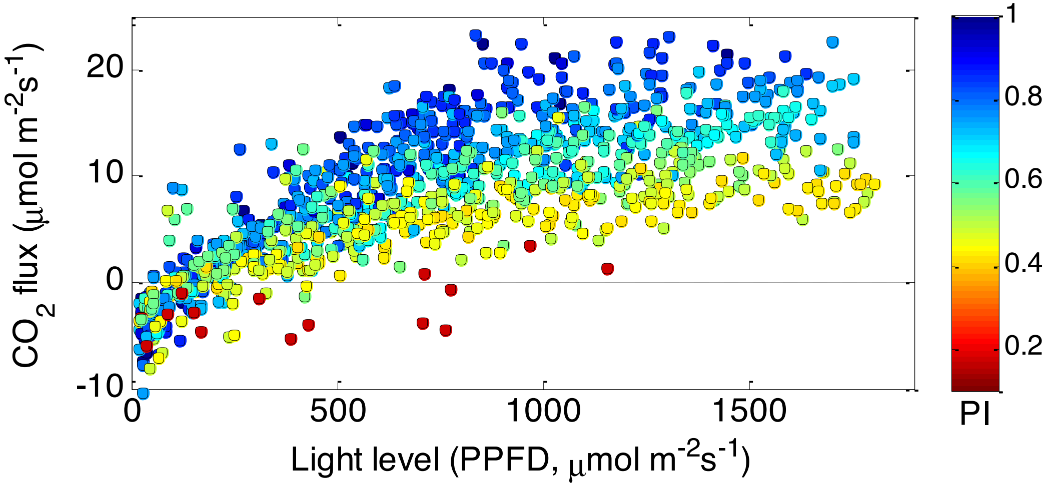
- August-October
- 30-minute daytime data

$$NEP = \alpha \cdot PPFD \cdot GP_{max} / \alpha \cdot PPFD + GP_{max}$$

- Light response curve shows lots of noise….
- …. or is it information?

Campbell, D. I., et al. (2015). Variations in CO_2 exchange for dairy farms with year-round rotational grazing on drained peatlands. Agriculture, Ecosystems & Environment, 202, 68-78.

Light-response of daytime CO_2 exchange – using PI

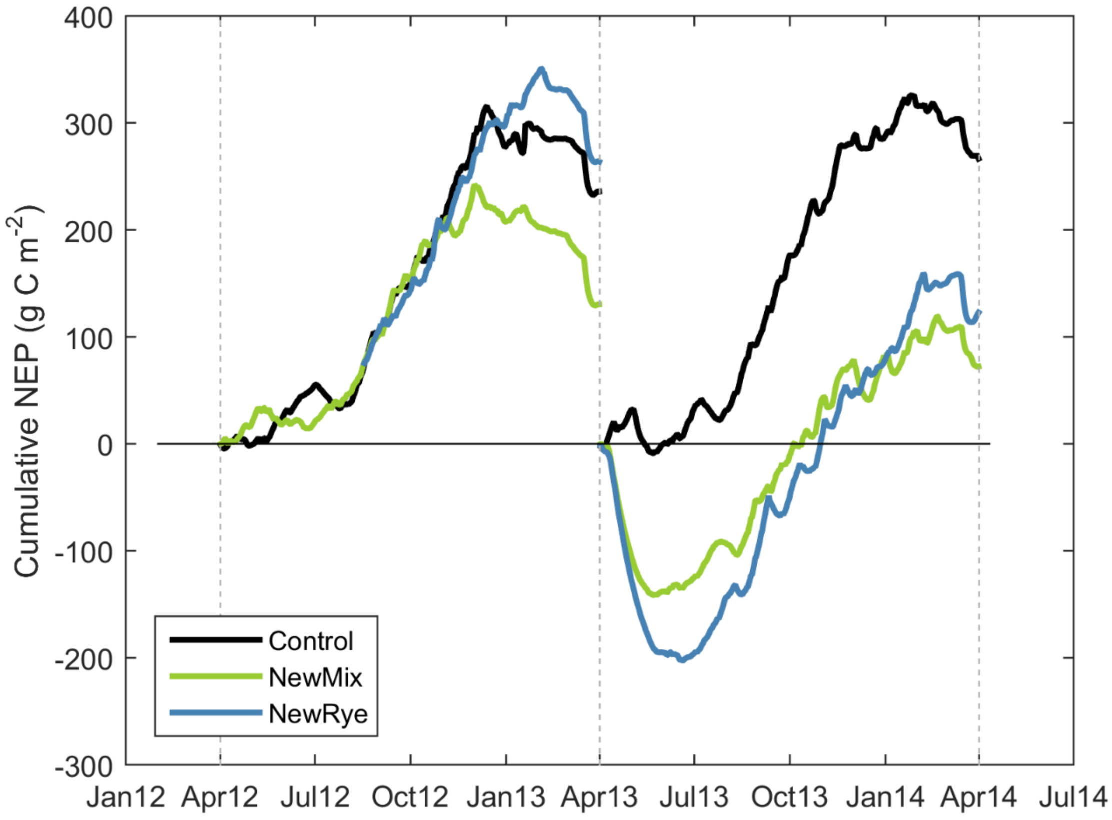


- Including PI improves predictive power
- Similar improvement when PI included into Neural Networks used for gapfilling

$$NEP = PI \times VPDI \times \frac{\alpha_{PI} \cdot PPFD \cdot GP_{\max}(PI)}{\alpha_{PI} \cdot PPFD + GP_{\max}(PI)} - ER_0$$

Campbell, D. I., et al. (2015). Variations in CO_2 exchange for dairy farms with year-round rotational grazing on drained peatlands. AEE, 202, 68-78.

CO_2 budgets in years before and after pasture renewal



Pasture renewal

Before pasture renewal

- CO_2 sinks
- Spatial variability due to impact of grazing and timing of grazing challenging!

Conclusions

- Important for CO_2 loss due to pasture renewal:
  - Moisture status of the soil
  - Method
  - Duration
- Evaporation: low spatial and interannual variation
- Grazing practices introduce large spatial and temporal variability in CO_2 fluxes
  - ❖ Phytomass index (PI) useful
  - ❖ Challenging to directly compare sites with asynchronous grazing

Current and planned work

- Develop full C balances for diverse sward and ryegrass-clover
- Water use and WUE of diverse sward
  Jack Pronger
- Supply data for modelling of scenario studies
  Miko Kirschbaum, Landcare Research
- Determine soil C stability
  Global Research Alliance work
  with Plant and Food and Landcare Research (with John Hunt)
- Continue to build collaboration with chamber-based N_2O programme of NZAGRC
  AgResearch
- Extend to N_2O and CH_4 at paddock scale
  Dave Campbell and postdoc Liyin Liang

Acknowledgements

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Landcare Research

DairyNZ for site access, data collection and advice

Ben and Sarah Troughton for site access and data collection

[redacted]

Potential benefits of mixed swards

- Increased drought resilience
- More even distribution of annual dry matter production and feed quality
- Improved nitrogen use efficiency of cows
    - ➢ Reduced leaching of urinary N?
    - ➢ Lower N_2O emissions?
- More and deeper roots
    - ➢ increase soil C at depth?