Soil carbon: Risks and opportunities in Aotearoa

Paul Mudge et al.

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Manaaki Whenua
Landcare Research

Outline

1. Importance of soil carbon (C)
2. How much C is in NZ soils?
3. Monitoring changes: national & farm scale
4. Effects of land use & management on soil C
5. Summary

Why is soil carbon important?

1. **Critical for soil health**
   - Maintenance of soil structural stability
     - Root growth, air/water movement, runoff/erosion
   - Food source for soil biota
   - Nutrient storage & cycling

2. **Feedbacks with climate via CO_2 <u>release</u> or <u>sequestration</u>**
   - Globally soils contain about twice as much C as the atmosphere
   - <u>Changes</u> could have a big impact on atmospheric CO_2 concentrations.
     - Risk and opportunity

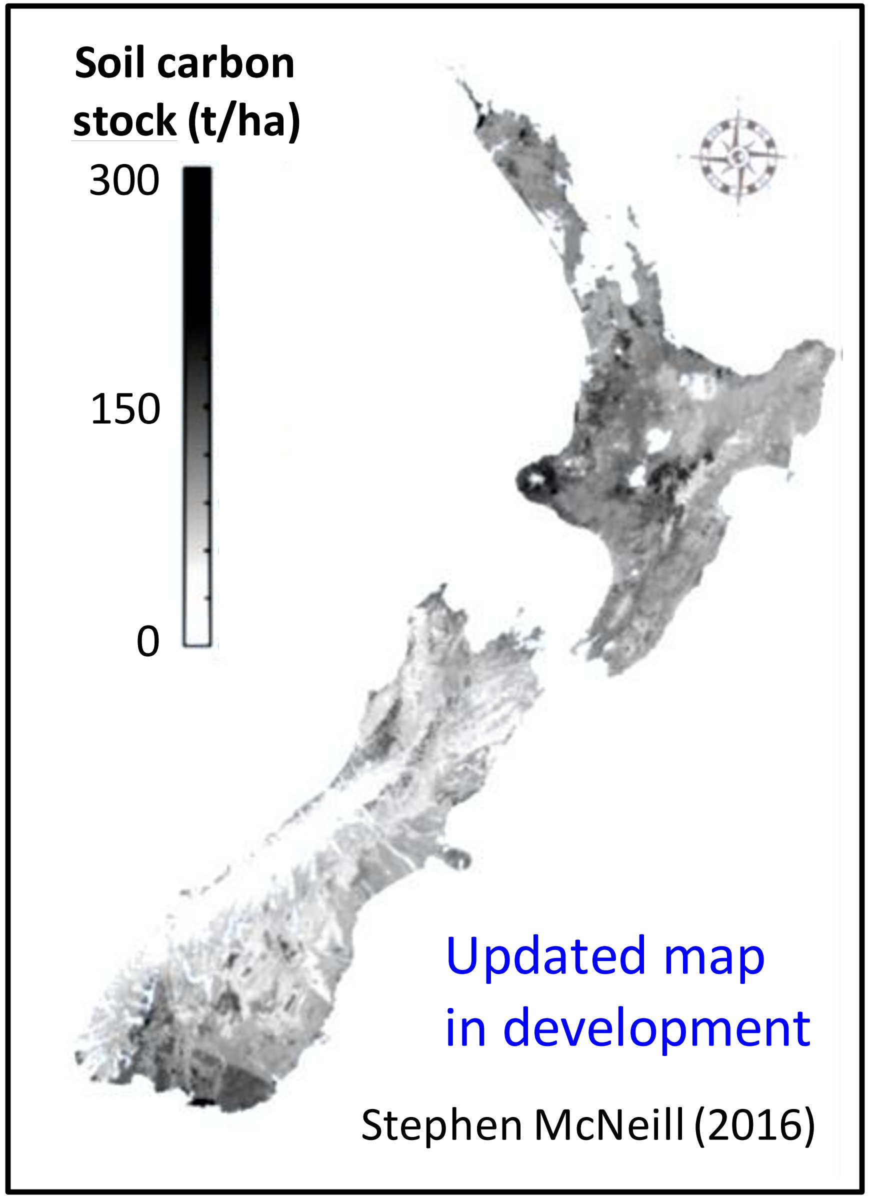
Carbon stocks in NZ soils

Soil C stocks to <u>30 cm</u> depth

- Compiled available data
- Developed spatial model & map

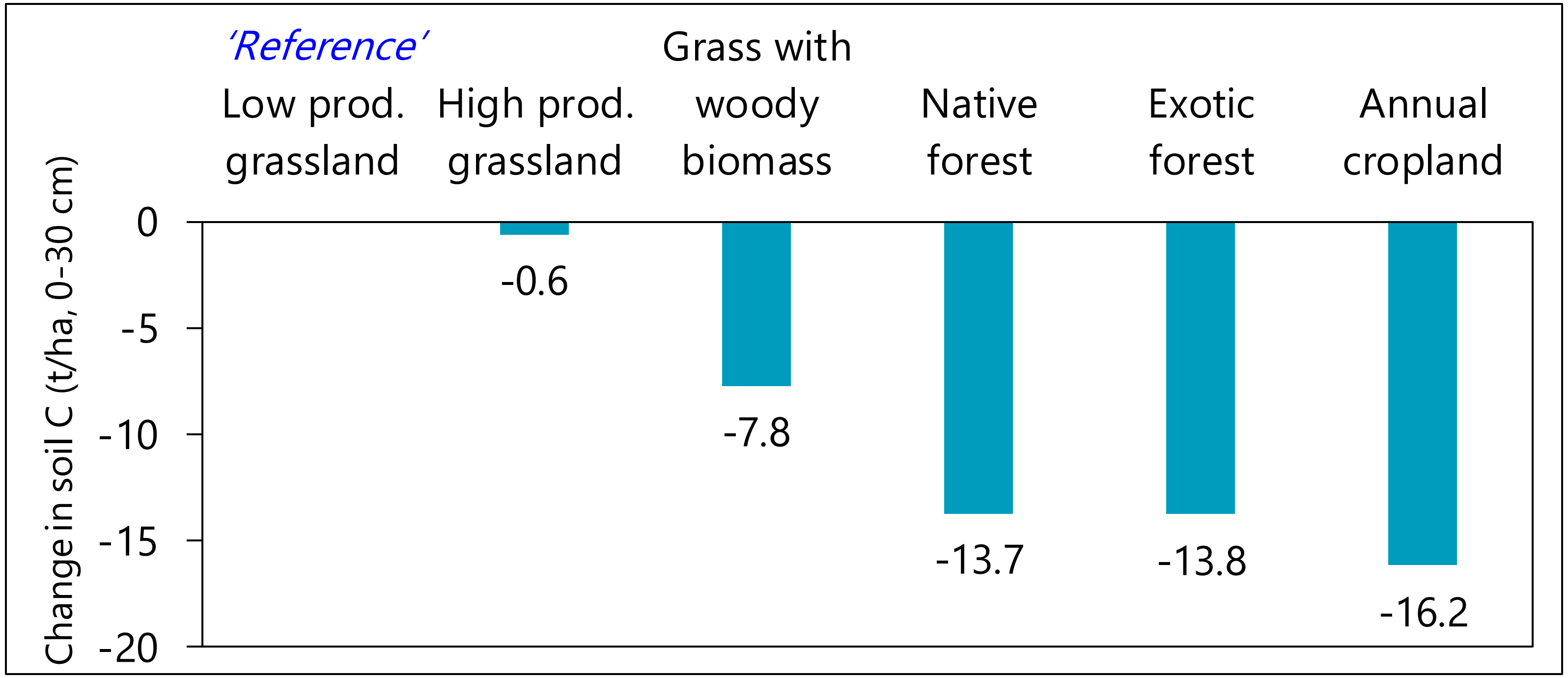
- **Average for all NZ:** ~**90 t ha^{-1}**
  - Australia ~30 t ha^{-1}
  - South Africa ~30 t ha^{-1}
  - Brazil ~40 t ha^{-1}
  - US ~45 t ha^{-1}
  - France ~70 t ha^{-1}

- NZ has lots of soil carbon
  - we want to maintain, or increase



Existing national ‘monitoring’ system

- National scale statistical model developed following IPCC methods
- Predicts <u>changes</u> in soil carbon stocks with **changes in land use**



McNeill, S.J.E., Golubiewski, N., Barringer, J., 2014. Development and calibration of a soil carbon inventory model for New Zealand. Soil Research 52(8), 789-804.

Existing national 'monitoring' system

Assumptions

- Equilibrium reached after 20 years for given land use
- Does not account for management within land uses
- Model is based on C data collected over decades, often for other purposes
  - Not fully representative of NZ's ag land.

Until recently, no system directly measuring changes in full profile soil C stocks for NZ's agricultural land

McNeill, S.J.E., Golubiewski, N., Barringer, J., 2014. Development and calibration of a soil carbon inventory model for New Zealand. Soil Research 52(8), 789-804.

New national benchmarking & monitoring system

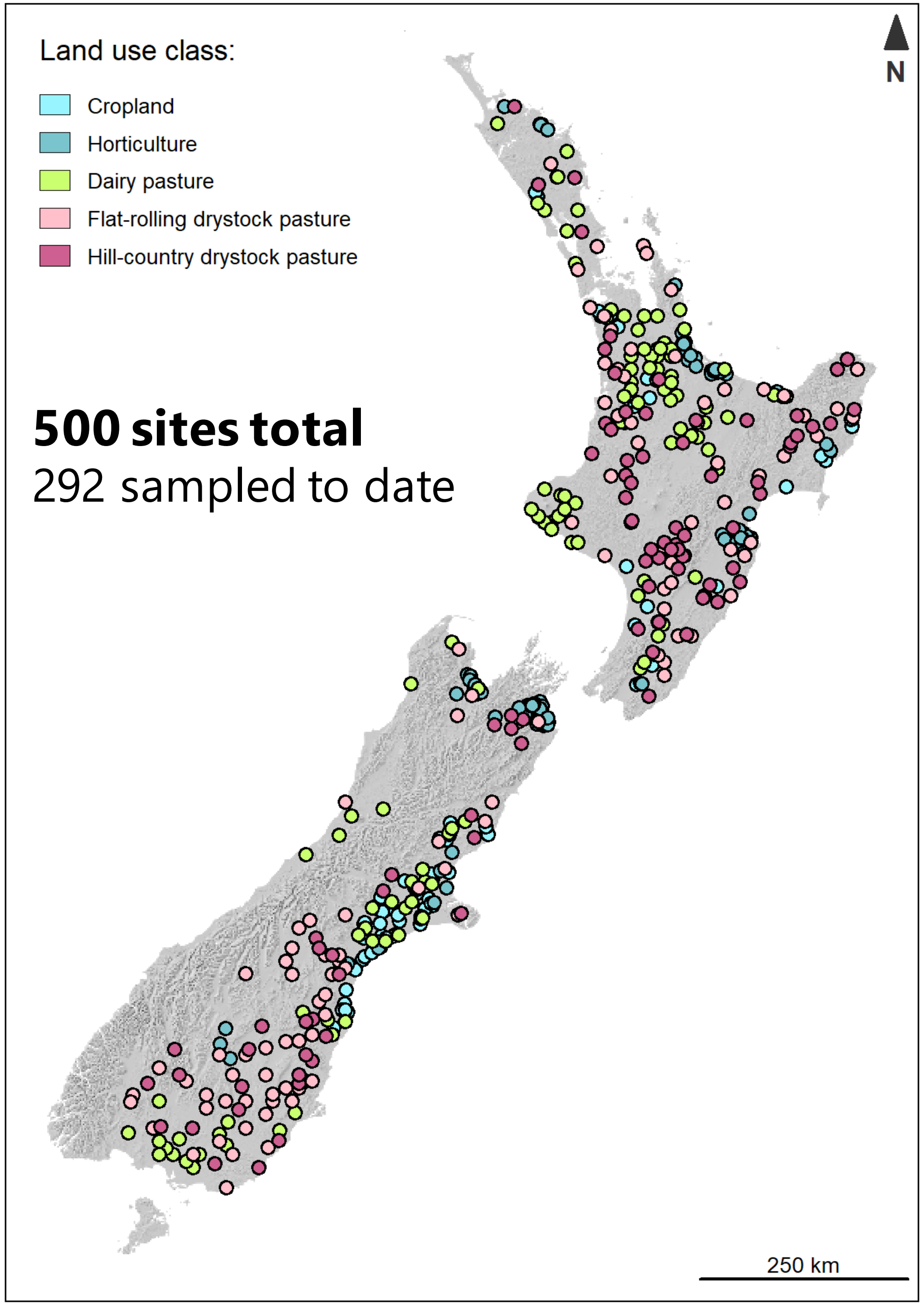
About 100 sites in each of five broad land use classes:

- Cropland
- Horticulture
- Dairy pasture
- Flat-rolling drystock
- Hill-country drystock

Sites randomly selected to ensure unbiased monitoring

Sampling to 0.6 m depth on a 4-year rolling schedule

- Benchmarking complete by 2023
- Data for three sampling times by 2031

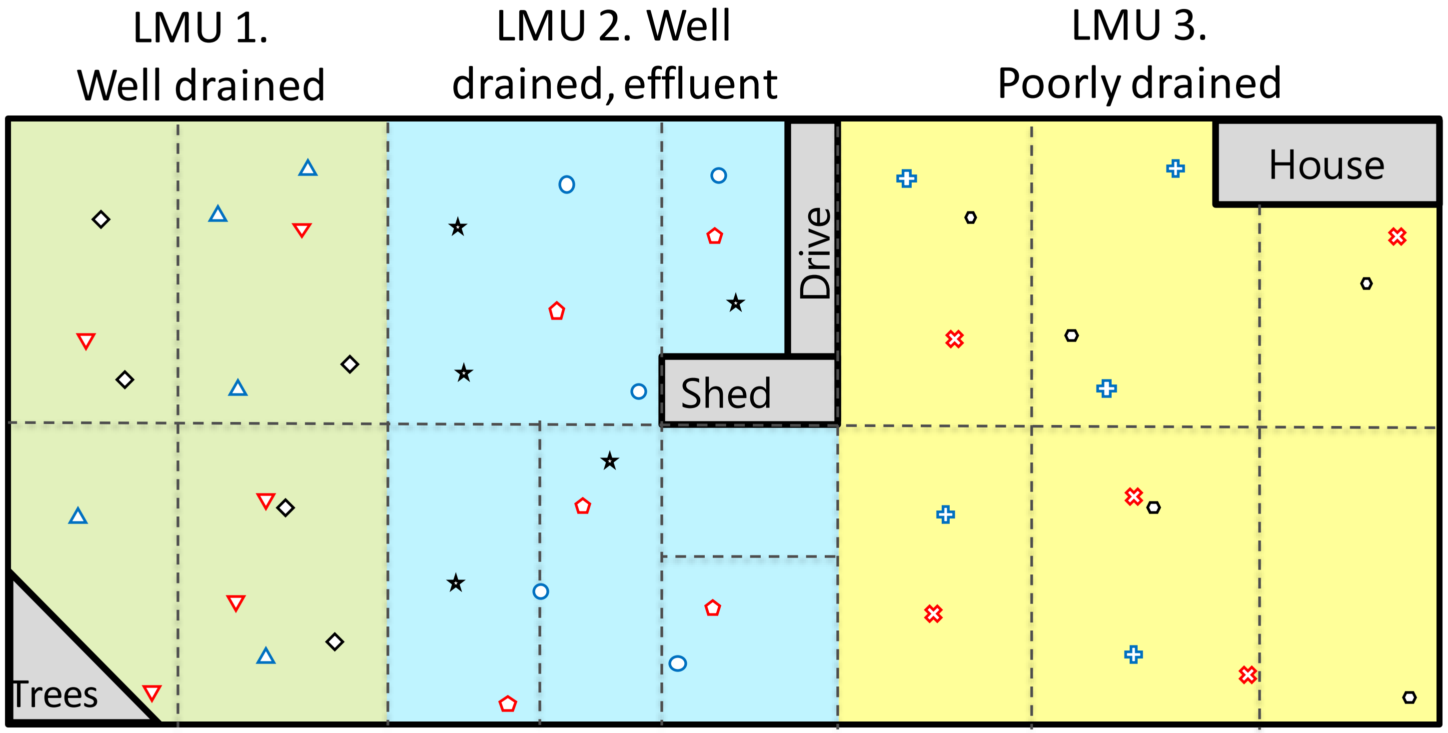


- Current study designed for the national scale.
- Potential to add more sites through regional or industry initiatives.

Design of an on-farm soil carbon benchmarking and monitoring approach for individual pastoral farms. MPI Technical Paper No: 2020/02.

Similar approach to the national scale system:

- Use land management units (LMU) in farm environment plans
- 'Random' allocation of sampling sites within LUMs



- Same soil sampling and processing methods
- Data can compliment the national scale programme

Mudge, P.L., McNeill, S., Hedley, C., Roudier, P., Poggio, M., Malone, B., Baldock, J., Smith, P., McNally, S., Beare, M., Schipper, L., 2020. Design of an on-farm soil carbon benchmarking and monitoring approach for individual pastoral farms. MPI Technical Paper No: 2020/02.

Specific studies on effect of land use & management

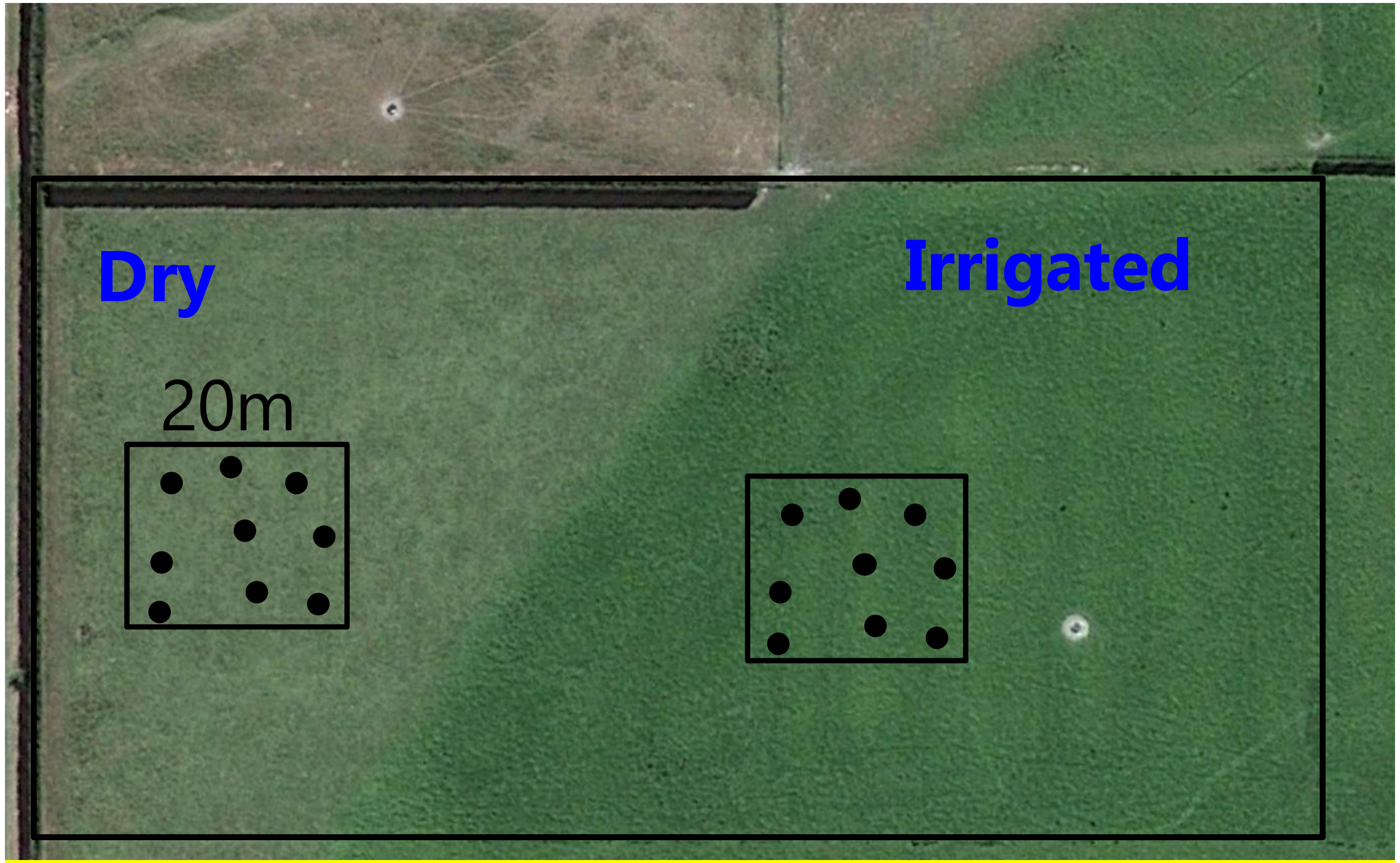
1. **Sampling existing long-term field experiments** (completed)
   - P fertiliser. No effect
   - Irrigation (Winchmore). Less C under well irrigated treatment vs dry

2. **National/regional sampling on commercial farms: paired site approach**
   - Dairy vs sheep & beef pastures (25 paired sites). Lower C in dairy topsoil
   - Irrigated vs dryland pastures
   - Maize cropping vs pasture

3. **Paddock-scale experimental manipulations**
   - Mixed species swards
   - Grazing management
   - Peatlands…
   - Trees in the landscape

Paired site approach:

Impact of irrigation on soil C and N stocks



5.2 t/ha less soil C under irrigation

124 paired sites across the country

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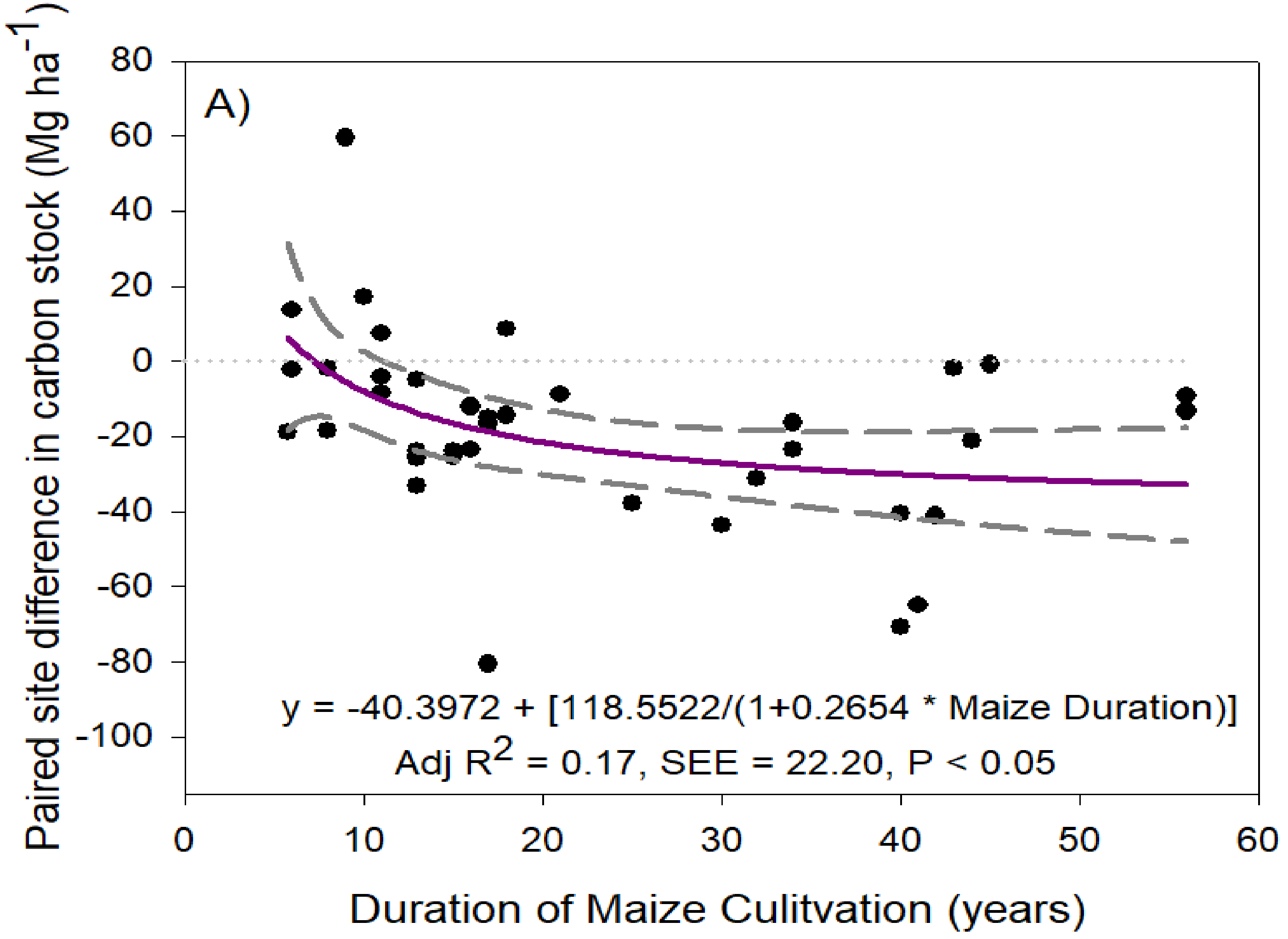
The University of Waikato
Te Whare Wānanga o Waikato

Mudge et al. (2021). Geoderma 399: 115109.
Mudge et al. (2017). Global Change Biology 23: 945-954.

Paired site approach:

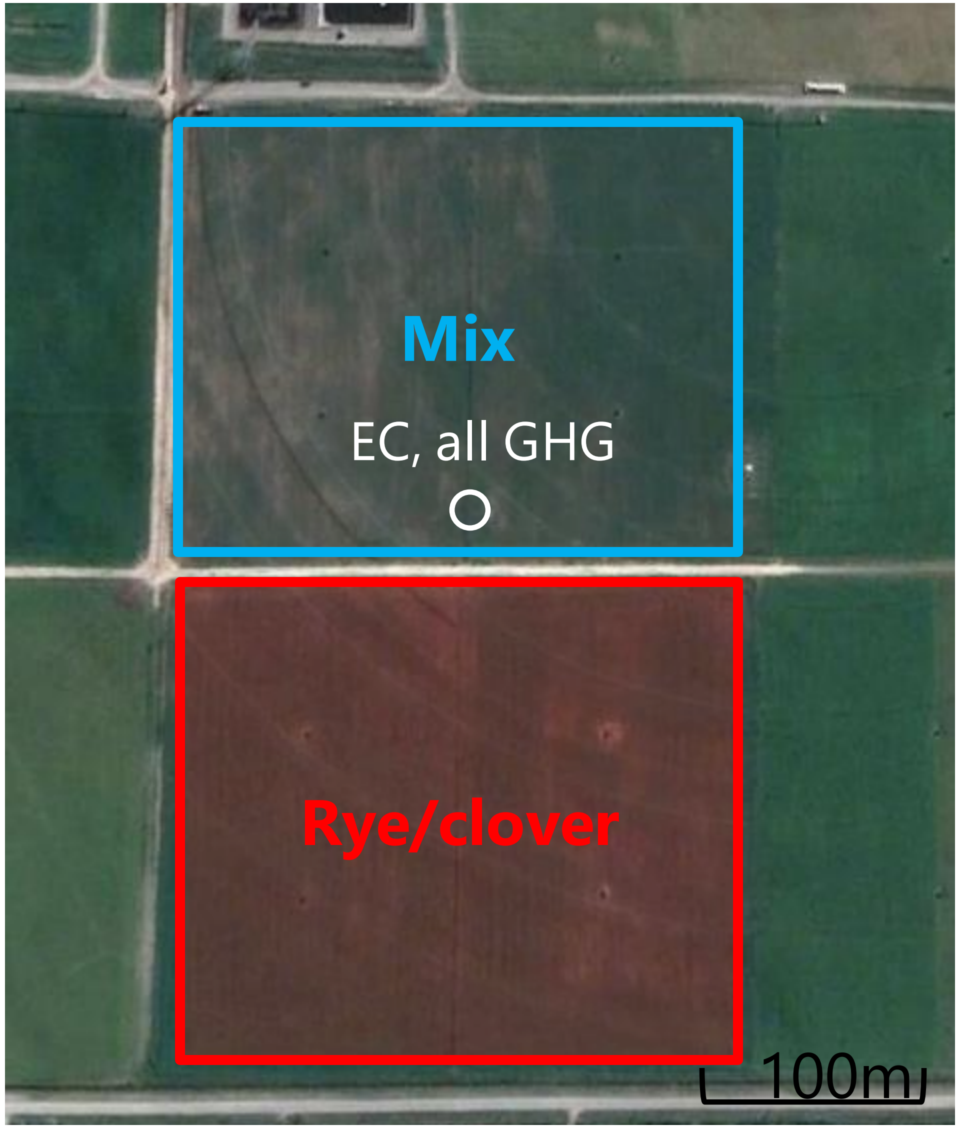
Maize vs pasture



- 41 paired sites in Waikato
- On average, C stocks **18.3** t ha^{-1} lower under maize than adjacent pasture

Mudge et al (in prep)

Paddock scale C & GHG balances:
Mixed sward vs conventional rye/clover



Paddock scale C & GHG balances:

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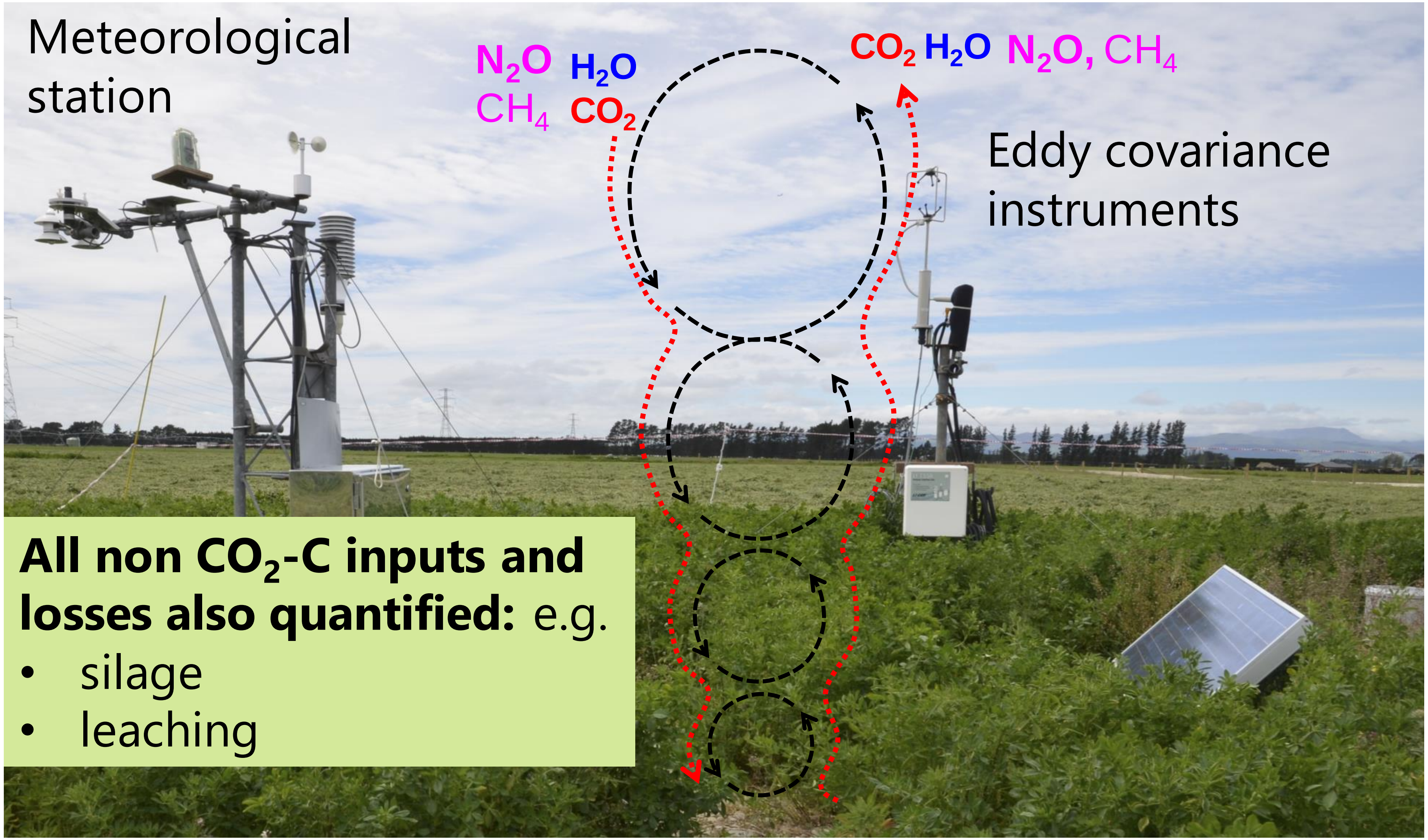
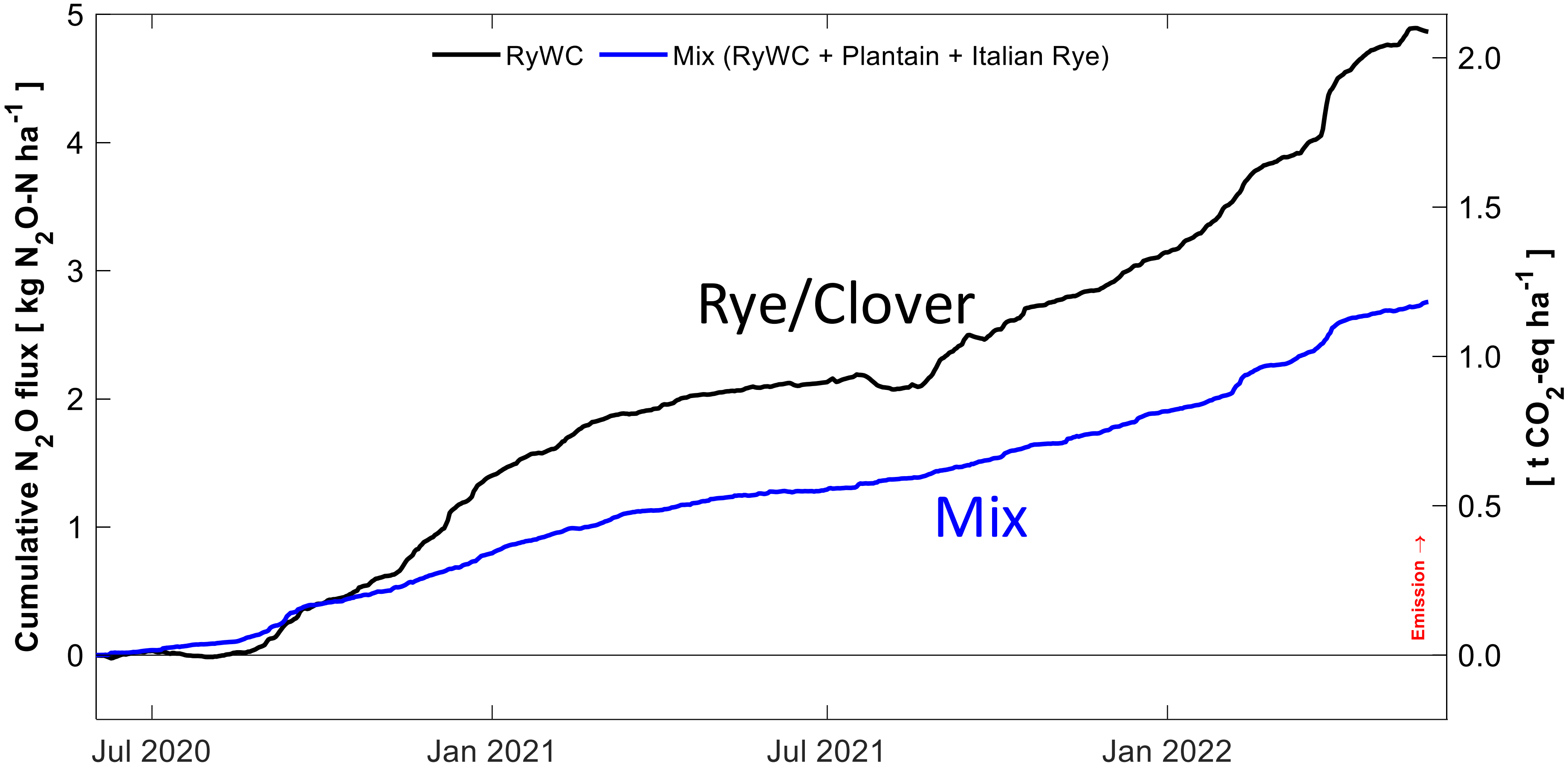


All non CO_2-C inputs and losses also quantified: e.g.

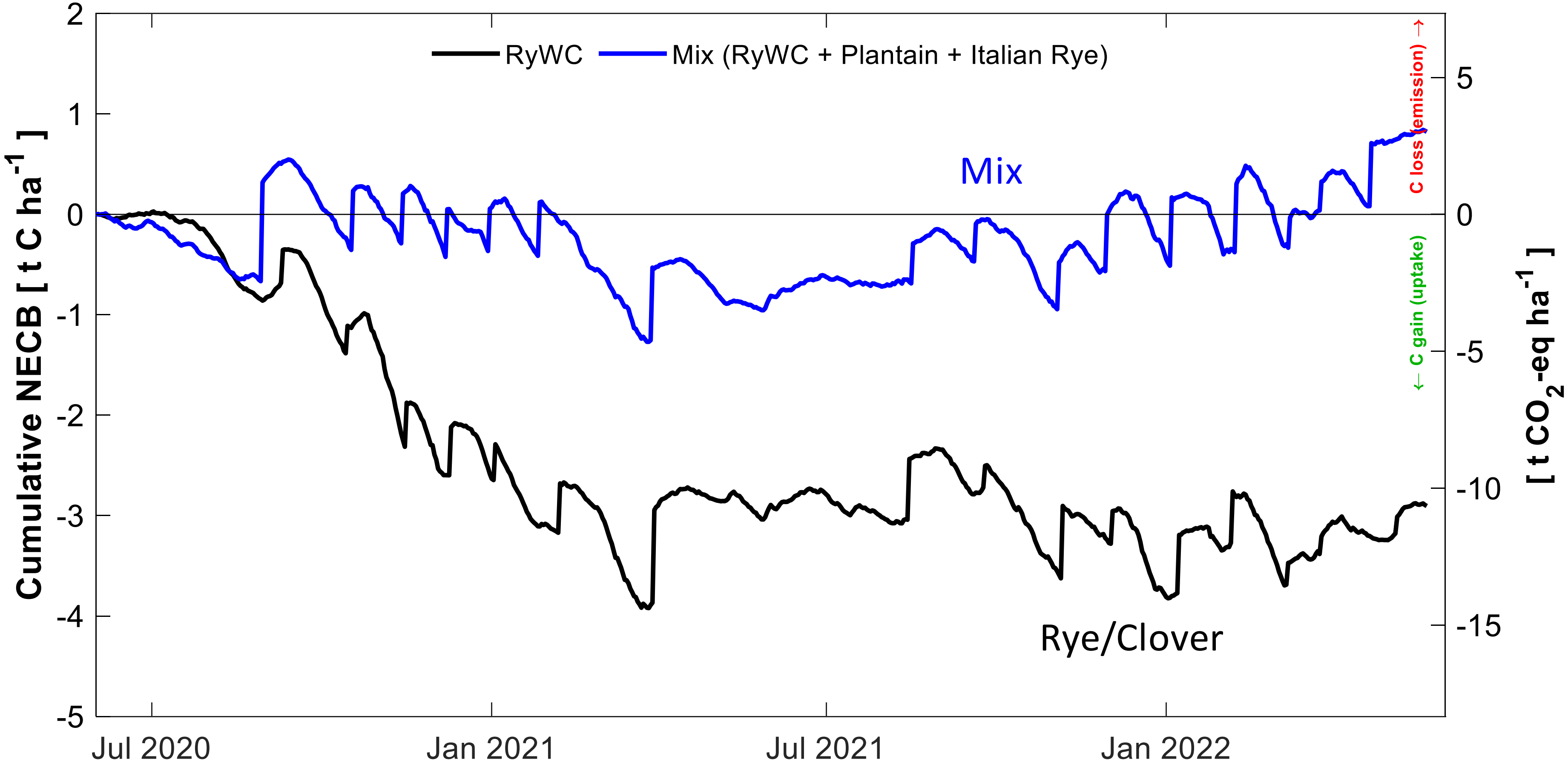
- silage
- leaching

39% less N_2O from mixed sward including Plantain and Italian rye than from rye/clover



Laubach et al. (submitted)

Carbon increased in ryegrass/clover but neutral in mixed sward
Overall, **total GHG** emissions higher from mixed sward



Carbon loss

Carbon gain

Laubach et al. (submitted)

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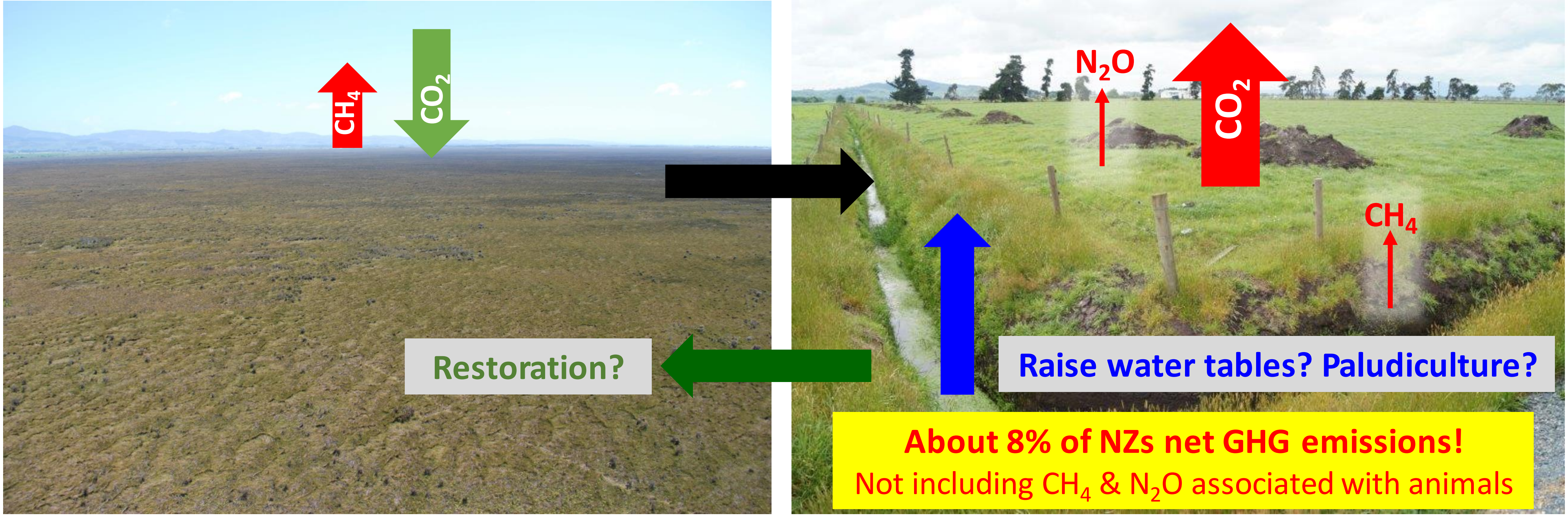
Carbon increased in ryegrass/clover but neutral in mixed sward
Overall, **total GHG** emissions higher from mixed sward

Need to consider impacts of mitigations on all GHG emissions

Identify synergies, or trade-offs

GHG emissions from peatlands

Intact peatland – Kopuatai example | **Drained peatland – Grassland example**



Peat Accumulation: 0.9 mm yr^{-1}

Soil GHG sink: -1.6 t $CO_{2\text{-eq}}$ ha^{-1} yr^{-1}

Peat Subsidence: 19 mm yr^{-1}

Soil GHG emissions: 21 t $CO_{2\text{-eq}}$ ha^{-1} yr^{-1}

Sources: Newnham et al., (1995), Pronger et al., (2015), Goodrich et al., (2017), Campbell et al., (2021).

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<u>New</u> MBIE programme: Trees in the landscape

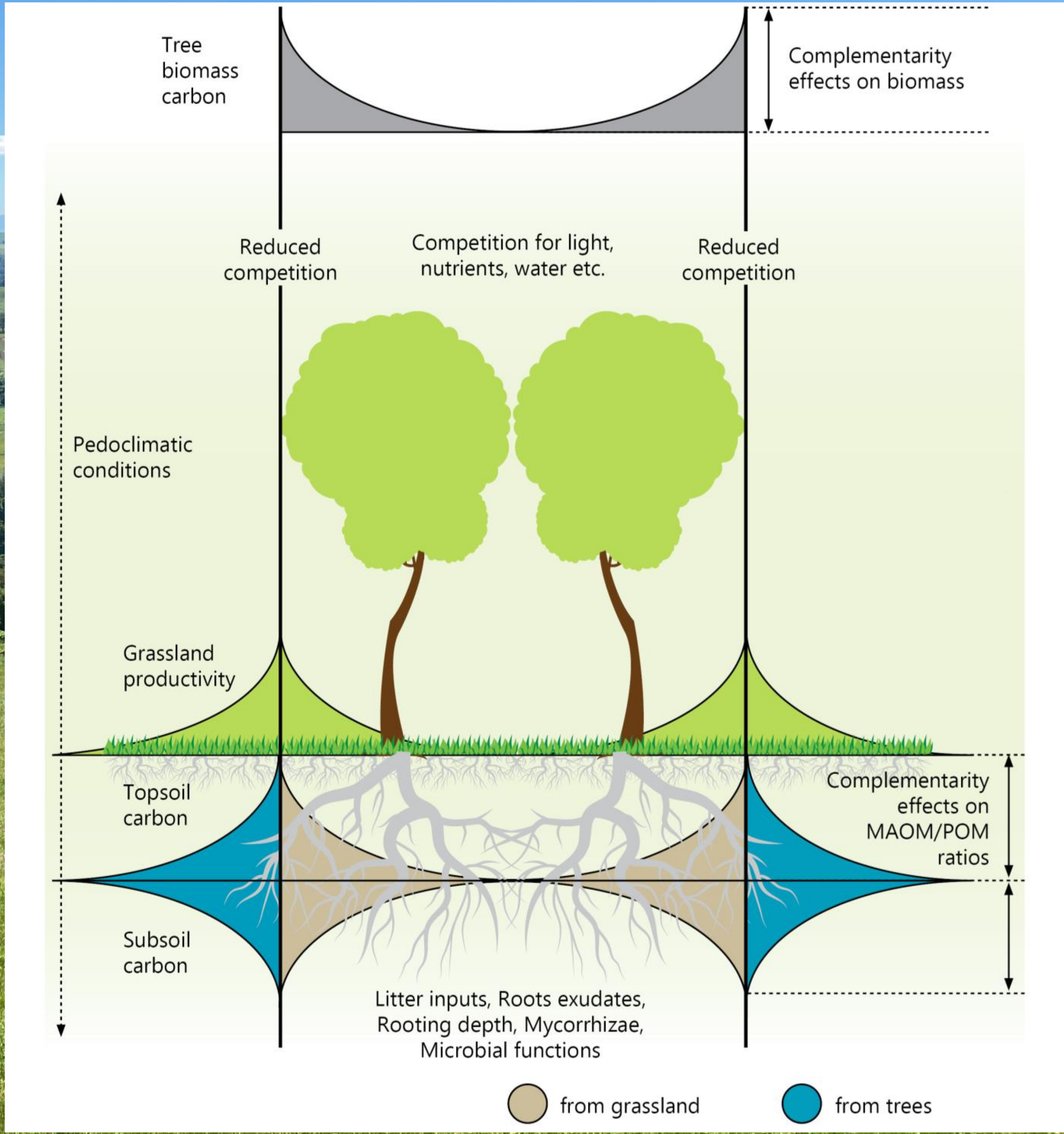
David Whitehead and Sam McNally

Carbon storage in biomass
Soil carbon
Reduced erosion

Fodder for animals
Commercial products (nuts, timber)
Biodiversity

Shelter for animals
Visual amenity
Cultural heritage

Focus on complementarity associated with edge effects



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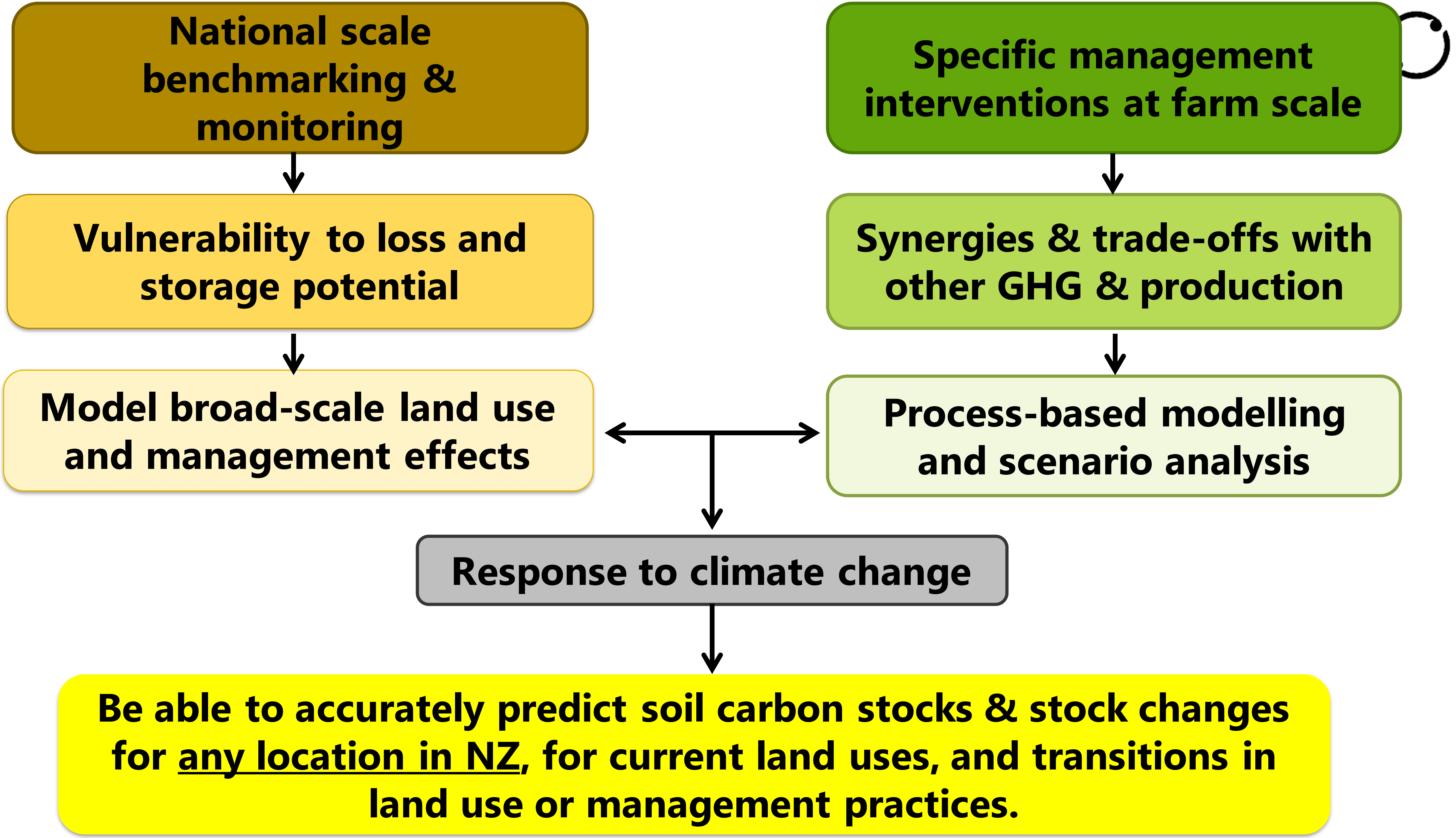
David Whitehead: WhiteheadD@landcareresearch.co.nz

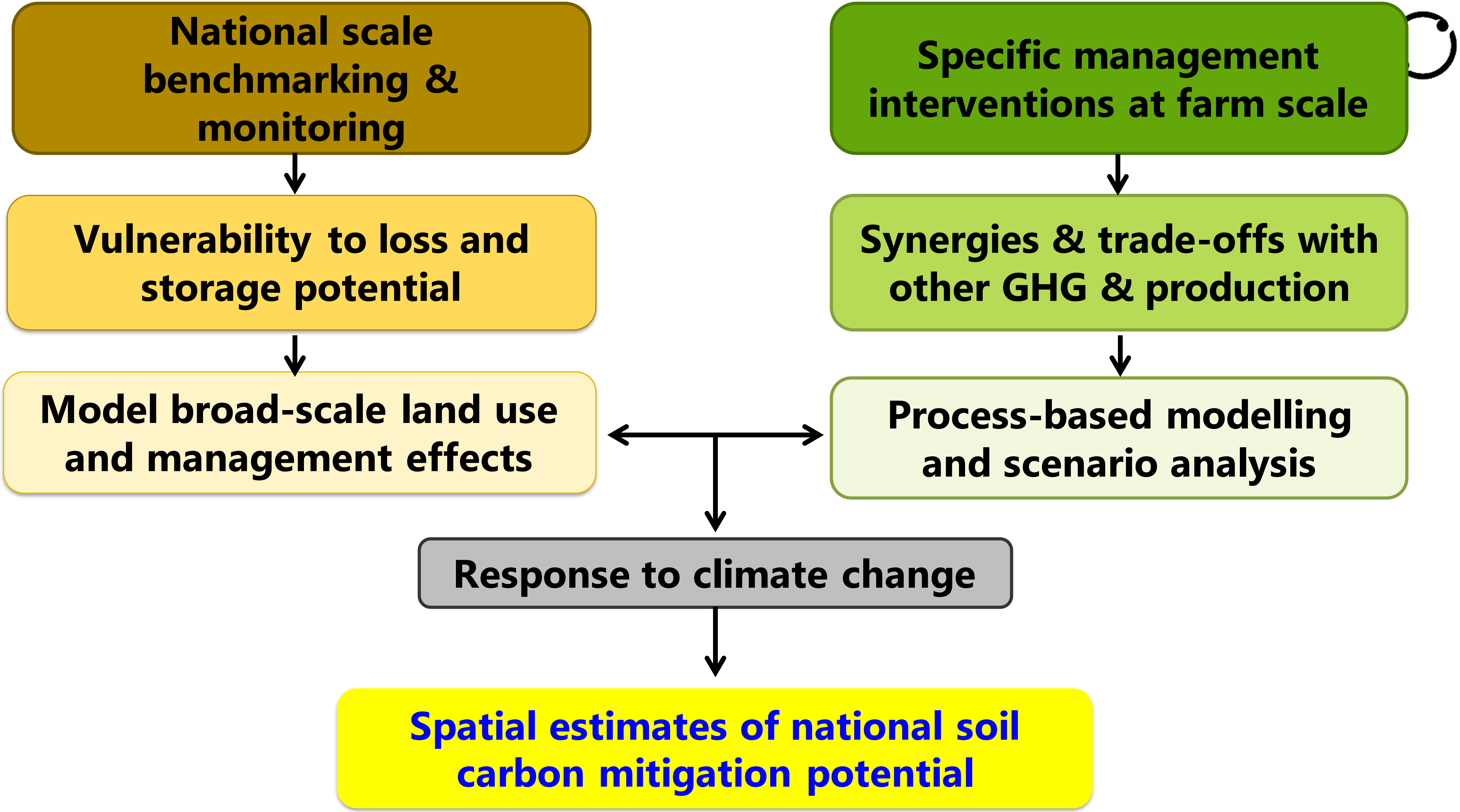
Summary

1. **In general, NZ has lots of soil carbon.** Imperative this is maintained or increased

2. **Benchmarking and monitoring** (national and farm scales)
   - A stake in ground for where we are at now
   - Are changes through time occurring?
   - Why are changes occurring?
     - Interactions between management, climate & soils?
   - Data will improve national GHG inventory modelling

3. **Effects of land use and management**
   - Soil C lower under irrigated pasture, long-term maize and mixed swards than adjacent dryland or conventional rye-clover pastures
   - Must consider impacts of mitigations on all GHG to identify synergies, or trade-offs
   - Drained peatlands are a large source of CO_2 emissions.
   - Projects on “Trees in the landscape” and “Grazing management” start soon


National scale benchmarking & monitoring
Vulnerability to loss and storage potential
Model broad-scale land use and management effects
Specific management interventions at farm scale
Synergies & trade-offs with other GHG & production
Process-based modelling and scenario analysis
Response to climate change
Be able to accurately predict soil carbon stocks & stock changes for any location in NZ, for current land uses, and transitions in land use or management practices.


National scale benchmarking & monitoring
Vulnerability to loss and storage potential
Model broad-scale land use and management effects
Specific management interventions at farm scale
Synergies & trade-offs with other GHG & production
Process-based modelling and scenario analysis
Response to climate change
Spatial estimates of national soil carbon mitigation potential

Acknowledgements

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- The many farmers who allowed access for soil sampling, or more in-depth studies

Some relevant references

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