

Getting the dirt: Improving agriculture through plant-soil interaction insights

SAMS Seminar, 30th Aug 2024
Dr Rose Boyko

Leading the way in Agriculture and Rural Research, Education and Consulting

Field research for land use

- Scottish Government: *Securing a green recovery on a path to net zero: climate change plan 2018–2032*:
 - “We must continue to produce **high quality food**, but also deliver high **environmental standards** and **emissions reductions**,
 - We will ensure that rural support enables, encourages and where appropriate requires the *shift to low carbon sustainable farming*.”
- Soil and ag-sector:
 - Reducing unnecessary emissions,
 - fertiliser, crop and livestock management, slurry storage, species selection, etc.
 - Storing CO₂ through soil organic matter (soil carbon),
 - Minimising land use change,
 - Restoring natural habitats.





- **Crop rotation** is the practice of alternating crops grown on a specific field each year in a planned pattern or sequence.
- Crop rotation vs continuous
 - Soil and plant pathogens/diseases more likely
 - Less productive over time
 - Soil quality degradation more likely.
- Of the holdings with arable land,
 - 85 per cent (3,600 ha) had at least 75 per cent or more land in general crop rotation (a total of 562,700 ha).

Smith, M.E., Vico, G., Costa, A. *et al.* (2023). **Increasing crop rotational diversity can enhance cereal yields.** *Commun Earth Environ* **4**, 89 <https://doi.org/10.1038/s43247-023-00746-0>

Reckling, M., Watson, C.A., Whitbread, A. *et al.* (2023). **Diversification for sustainable and resilient agricultural landscape systems.** *Agron. Sustain. Dev.* **43**, 44 <https://doi.org/10.1007/s13593-023-00898-5>

Costa, A., Bommarco, R., Smith, M. E, *et al.* (2024). **Crop rotational diversity can mitigate climate-induced grain yield losses.** *Global Change Biology*, **30**, e17298. <https://doi.org/10.1111/gcb.17298>

Long and short-term experimental sites, SRUC

**pHoenix
Long Term
Experiment**
(LTE), SRUC
Craibstone,
Aberdeen

**Tulloch
Organic LTE,**
SRUC
Craibstone,
Aberdeen

**Intercropped
Species
trial,** SRUC
Craibstone,
Aberdeen

**Nitrous
Oxide
Emission
trial,** Kirkton,
Crianlarich

Watson, C. A., Topp, C. F. E., Mead, A., *et al.*, (2024). **Future proofing a long-term agricultural experiment for decades to come: Relocation and redesign.** *European Journal of Agronomy*, 158, 127214.

Willoughby, C.M., Topp, C.F., Hallett, P.D. *et al.* (2023). **Soil health metrics reflect yields in long-term cropping system experiments.** *Agron. Sustain. Dev.* 43, 65
<https://doi.org/10.1007/s13593-023-00919-3>

In a diversity of ways, SRUC field experiments contribute to improving agricultural rotations – or aspects within rotations – to improve soil, yield, nutritional quality, efficiency, nutrient cycles, etc.

Total Scottish agricultural area
in 2023 was 5.33 million
hectares (69% of total land).

**Nitrous Oxide
Emission trial,**
Kirkton,
Crianlarich

**pHoenix Long
Term
Experiment
(LTE), SRUC
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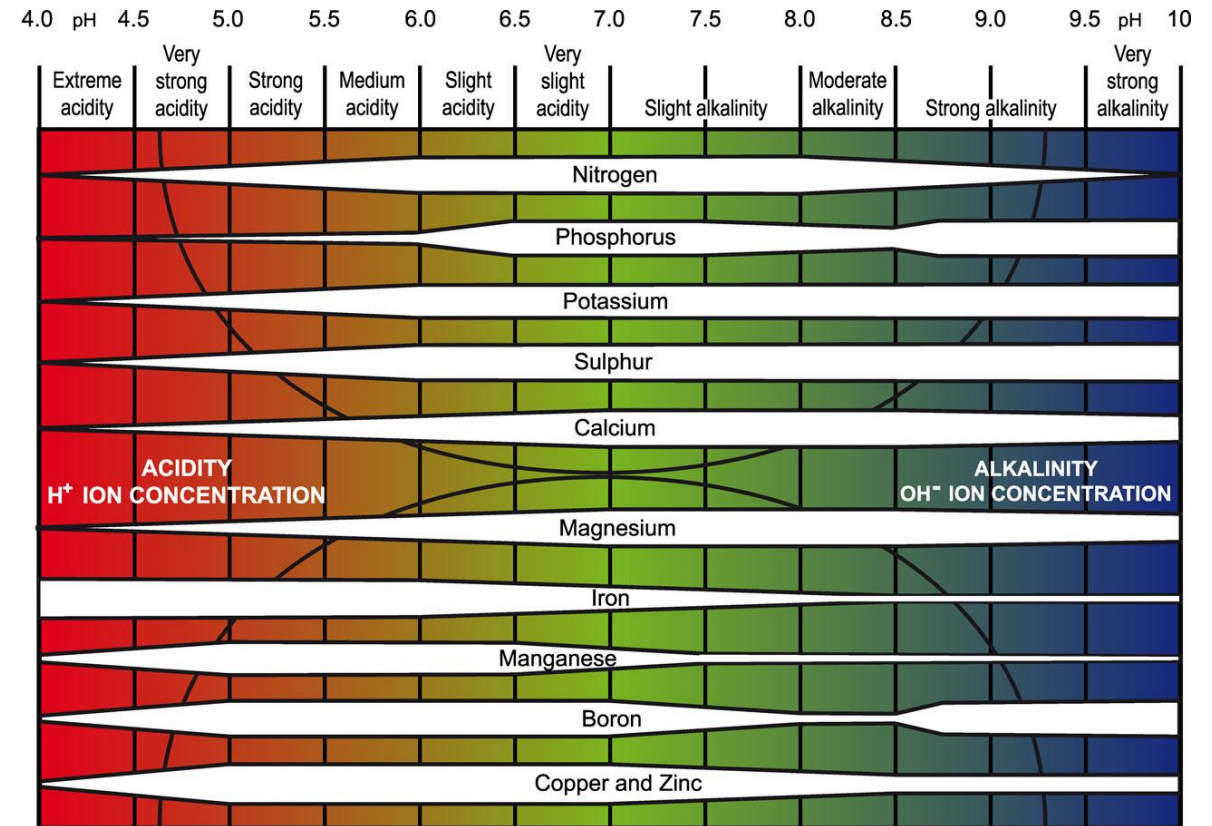
Classification



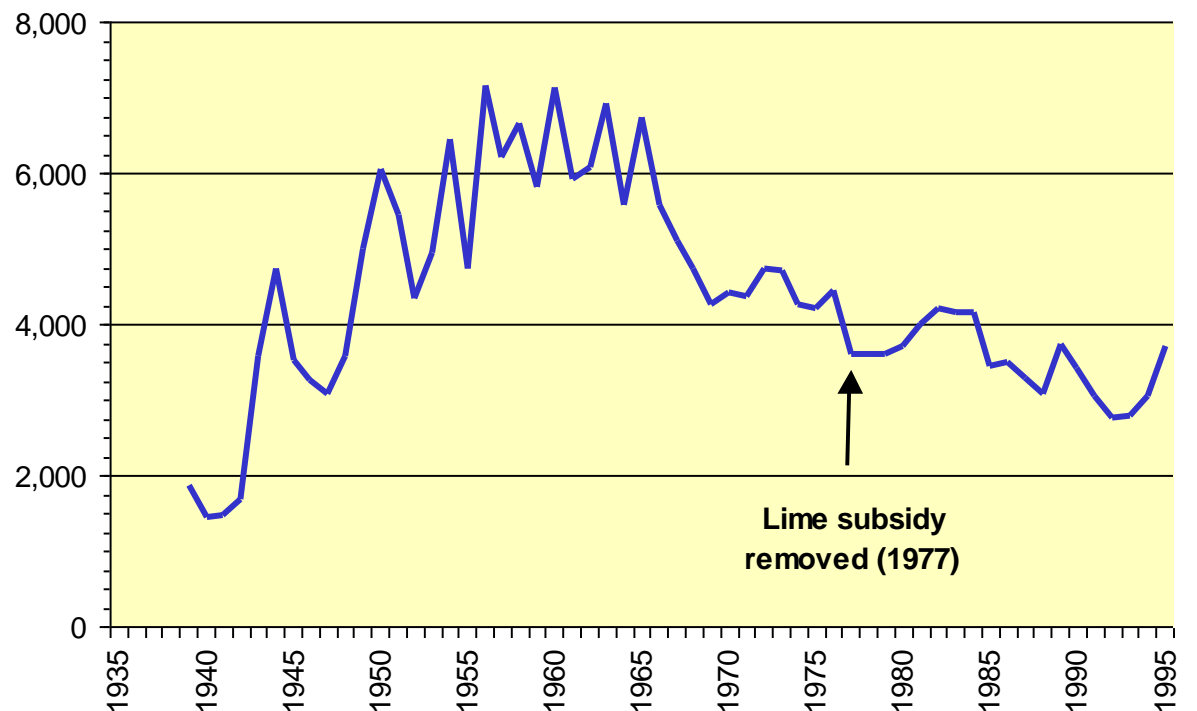
How does soil pH influence grazed grassland sward yield and nutritional quality?

- Soil pH values are a measure of hydrogen ions – indicates soil acidity or alkalinity
- Noted concern for decline in agricultural soil pH values – less liming the last 20+ years (Goulding, 2016; Edwards et al., 2016; Holland et al., 2018).
- “Master soil variable” that effects,
 - Biological,
 - Physical,
 - Chemical aspects of soil

→ plant → animal

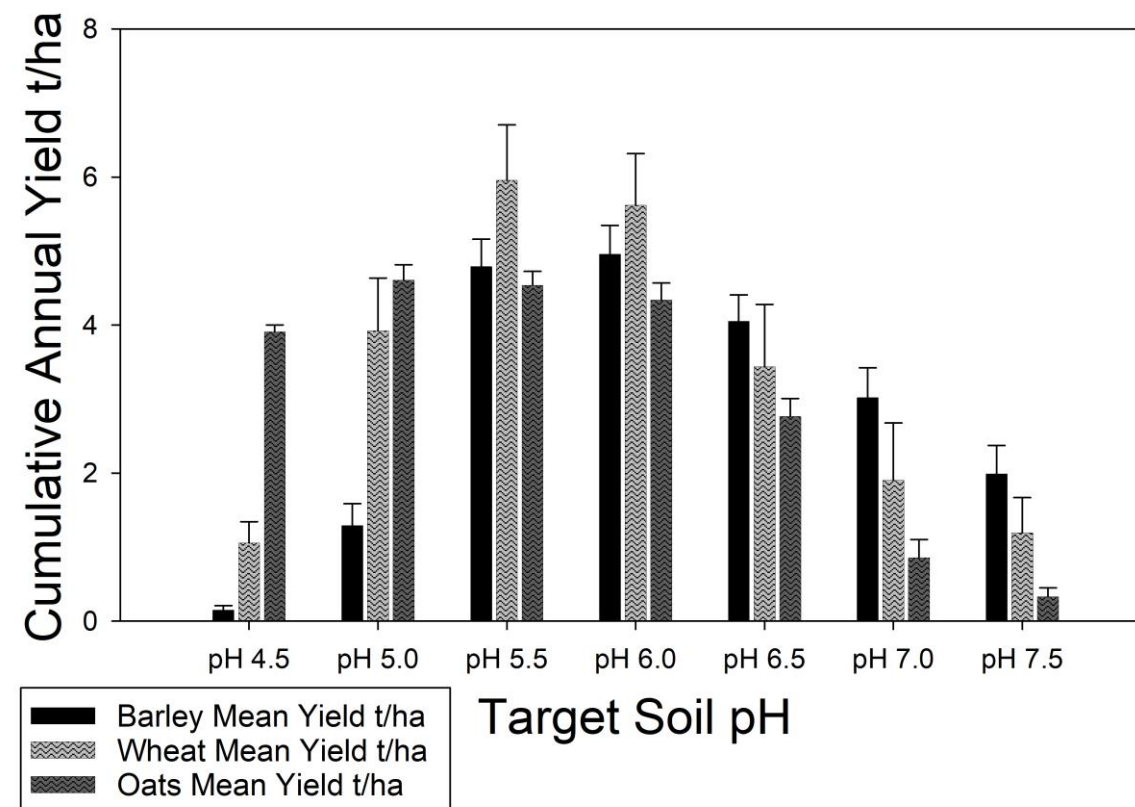


How does soil pH influence grazed grassland sward yield and nutritional quality?



Estimated annual lime product use (kt) in the UK over time from ALPC, MAFF and DEFRA. ^[1]

^[1] This data is an estimate and does not account for percent effective neutralizing value of total liming materials. This data is mostly representative of England with few additional sources from other parts of the UK.



How does soil pH influence grazed grassland sward yield and nutritional quality?



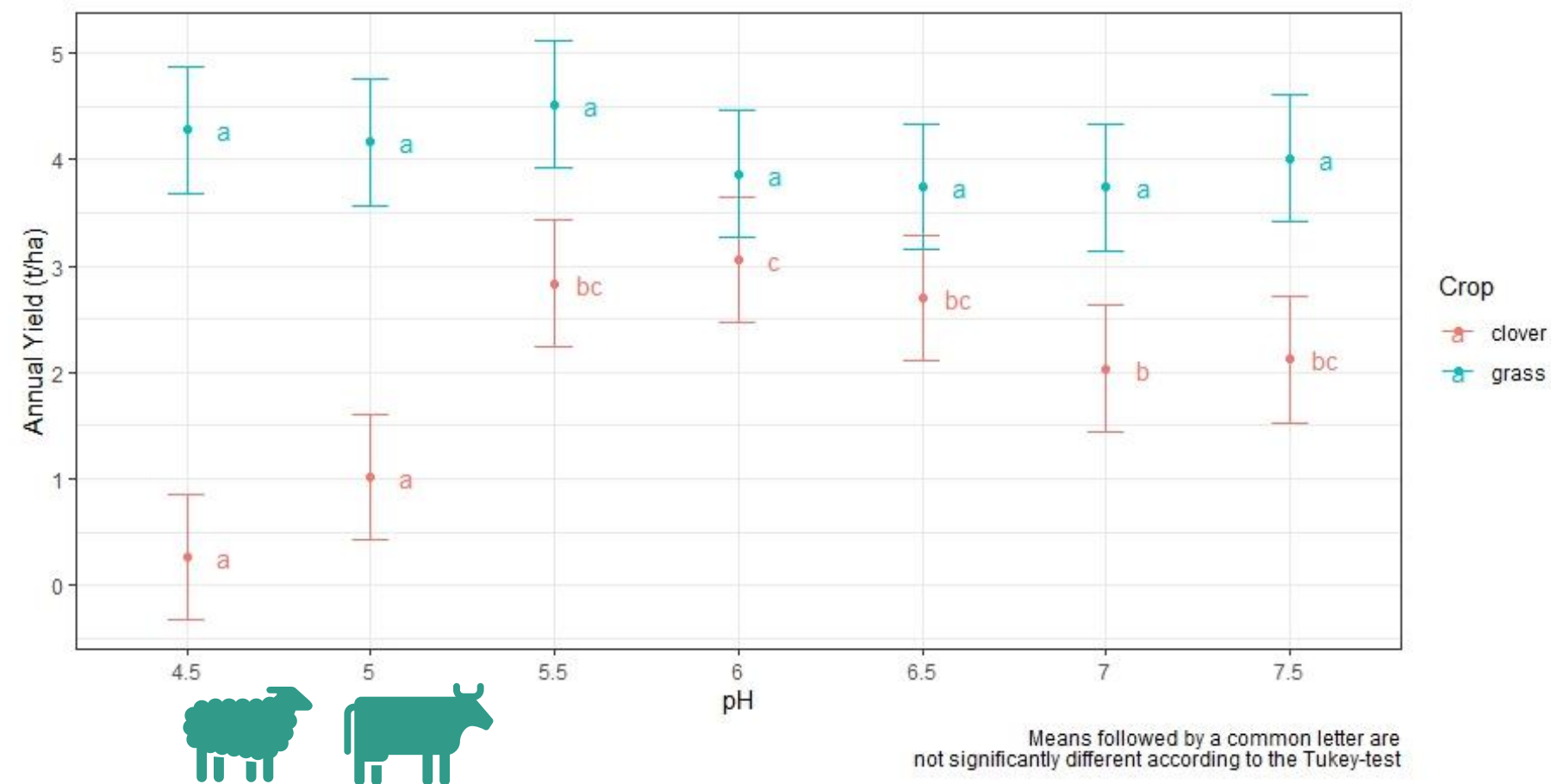
- Woodlands field long-term pH experiment
 - Est 1961
 - Eight-course ley-arable crop rotation
 - Grass-clover year 1 hay, **grass-clover year 2, 3 grazed**, winter wheat, potatoes, spring barley, swedes, and spring oats (undersown with the grass-clover).
 - Sandy loam soil (Countesswells association)
 - pH 0.5 value increments
 - pH 4.5 to 7.5



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Term

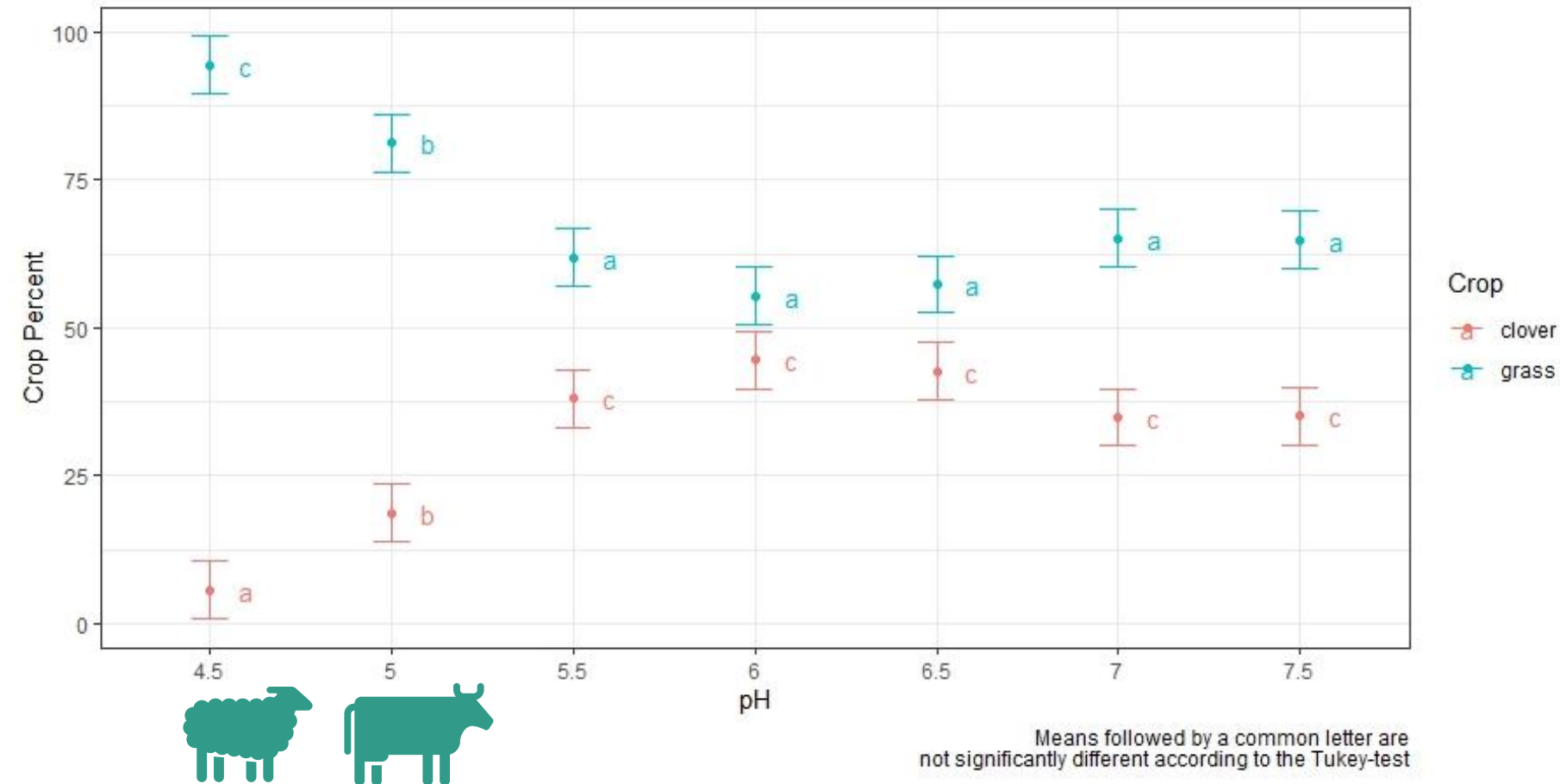
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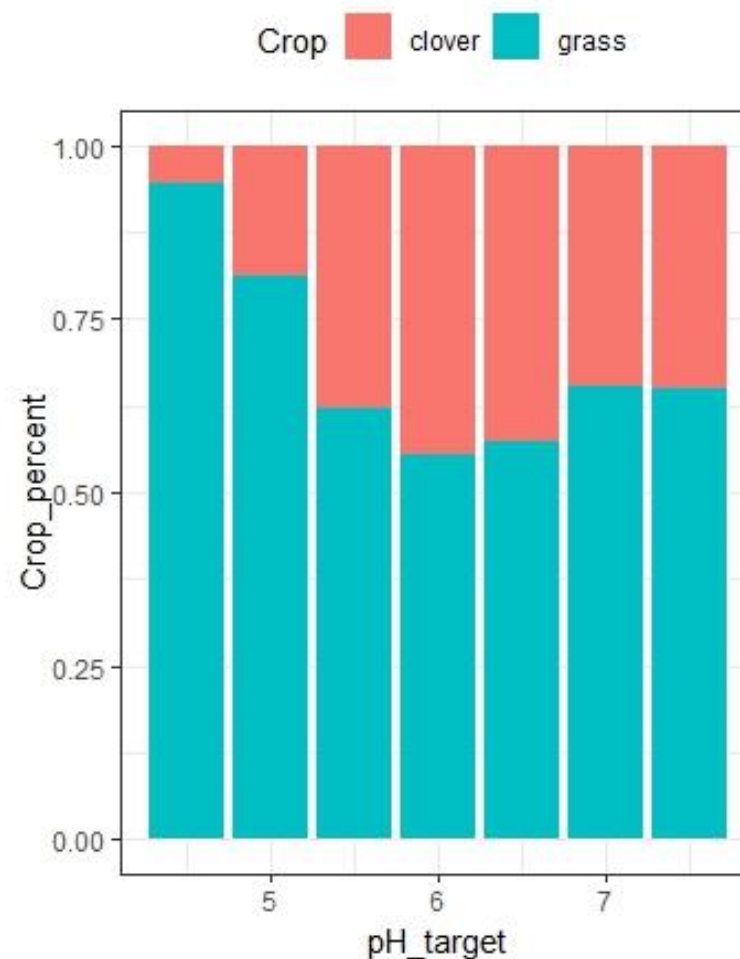
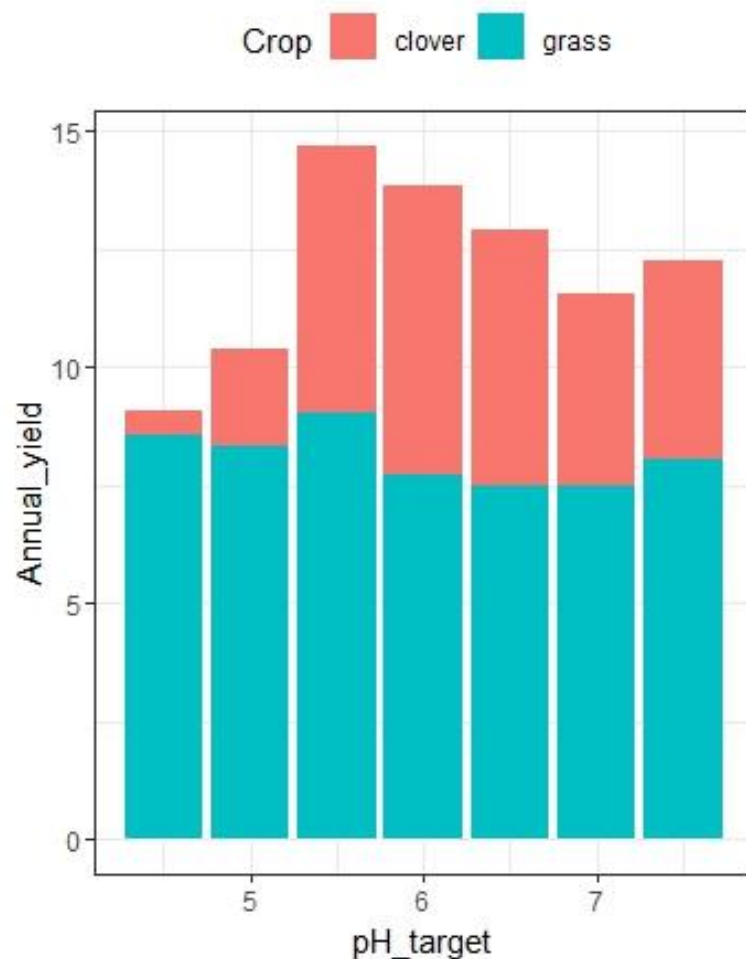
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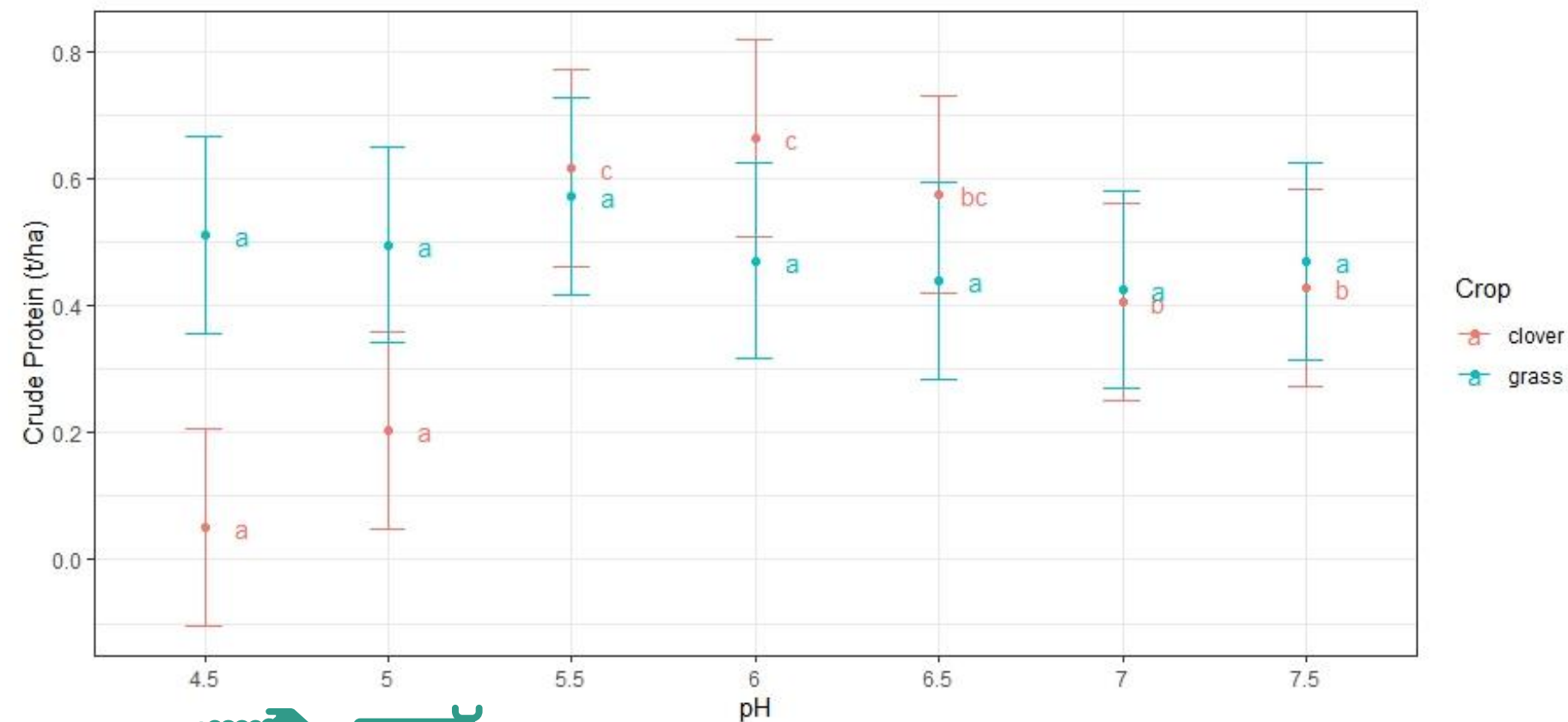
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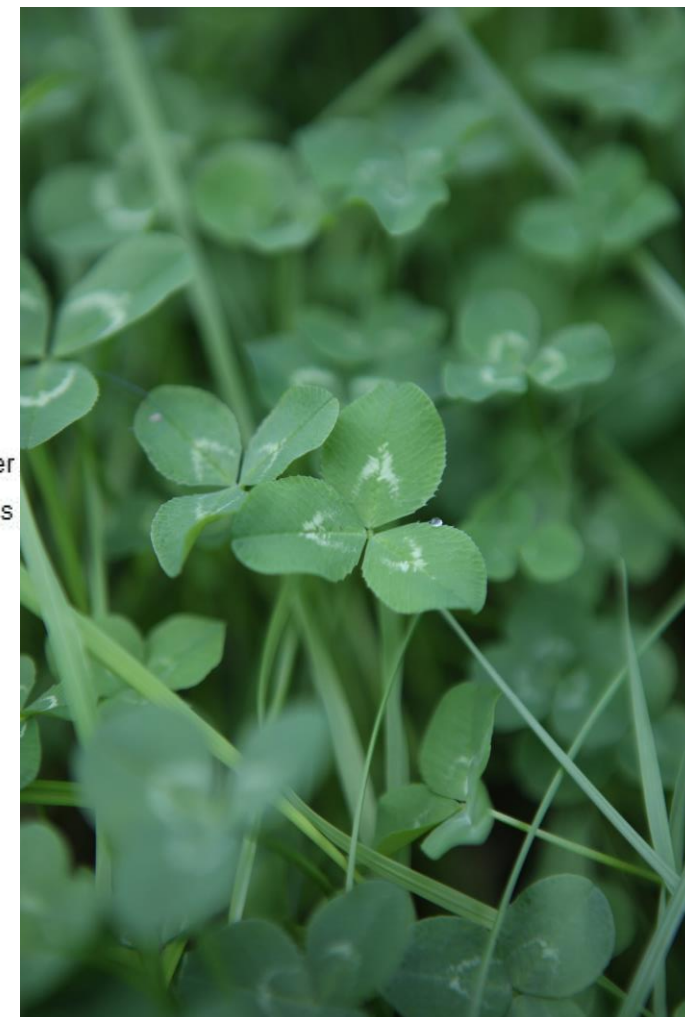
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Term

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How does soil pH influence grazed grassland sward yield and nutritional quality?



Means followed by a common letter are not significantly different according to the Tukey-test

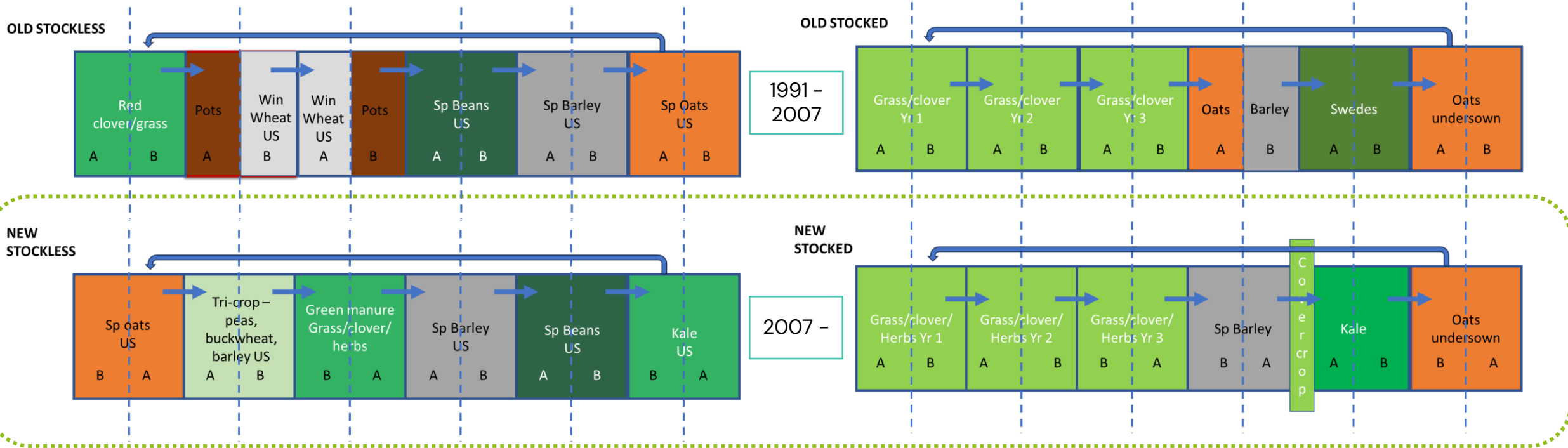


How does soil pH influence grazed grassland sward yield and nutritional quality?

- Estimated by increasing the proportion of WC from 0.0 to 31.6% would result in 1.4–1.6 kg/day milk yield increases (Dineen et al., 2018; Johansen et al., 2018).
- The increase in daily milk yield could increase by approximately 500 L per cow/year at a pricing of £0.32/L resulting in £160 additional milk sales/year/cow (Rumsey, 2022).
- In an 80–cow herd, this would translate to approximately £12,800 higher net income.



In stocked versus stockless organic farming rotations, how and where is soil carbon stored?



In the late 1980's / early 1990's interest in organic agriculture was on the rise...

- What fertility building rotations should be targeted in organic systems in NE Scotland?
- Will these targets differ for different soils and climate?

Tulloch in 2024 asks...

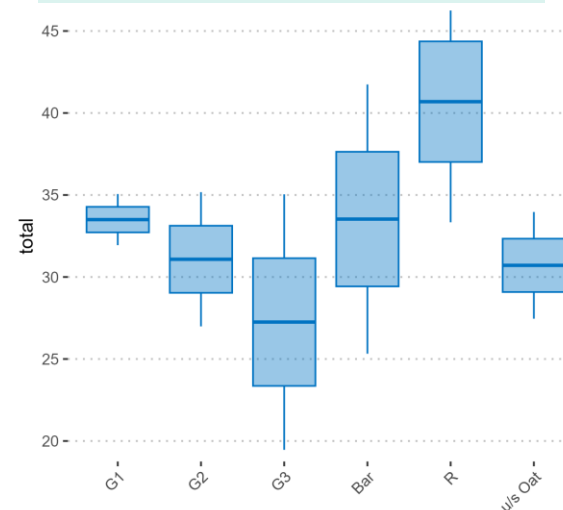
- What is the effect of stocked vs stockless on soil and yield?
- Is a “vegan” system leaning heavily on legumes effective?

In stocked versus stockless organic farming rotations, how and where is soil carbon stored?

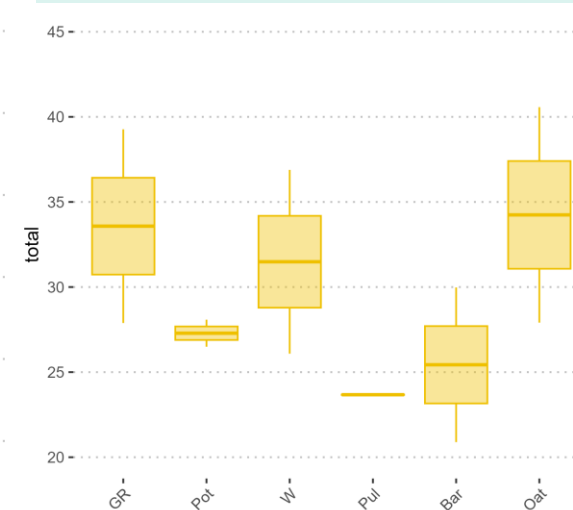
Key takeaway:

- A stocked system has a greater opportunity to increase soil C than stockless

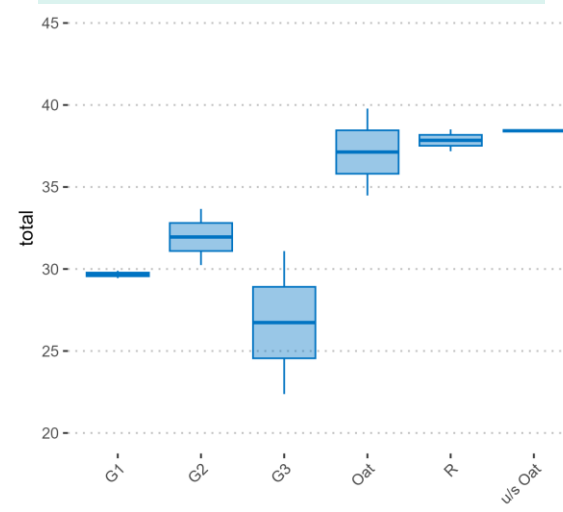
Stocked = mixed subplot A



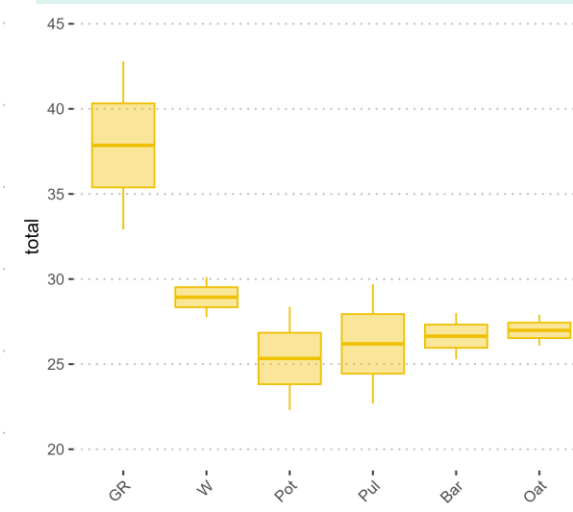
Stockless = stockless subplot A



Stocked = mixed subplot B



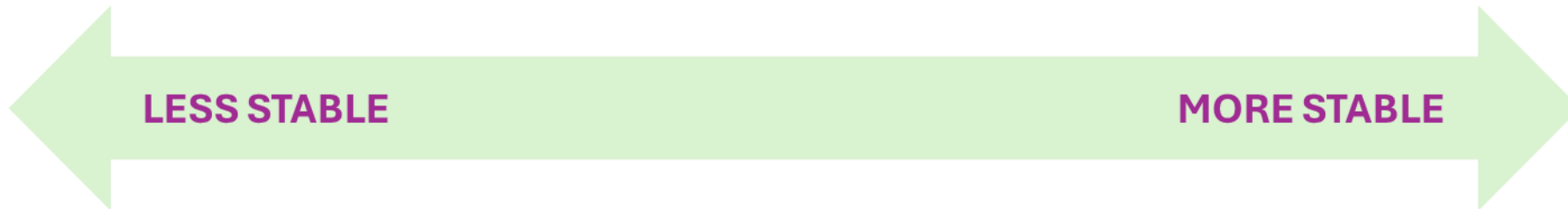
Stockless = stockless subplot B



Soil carbon fractions

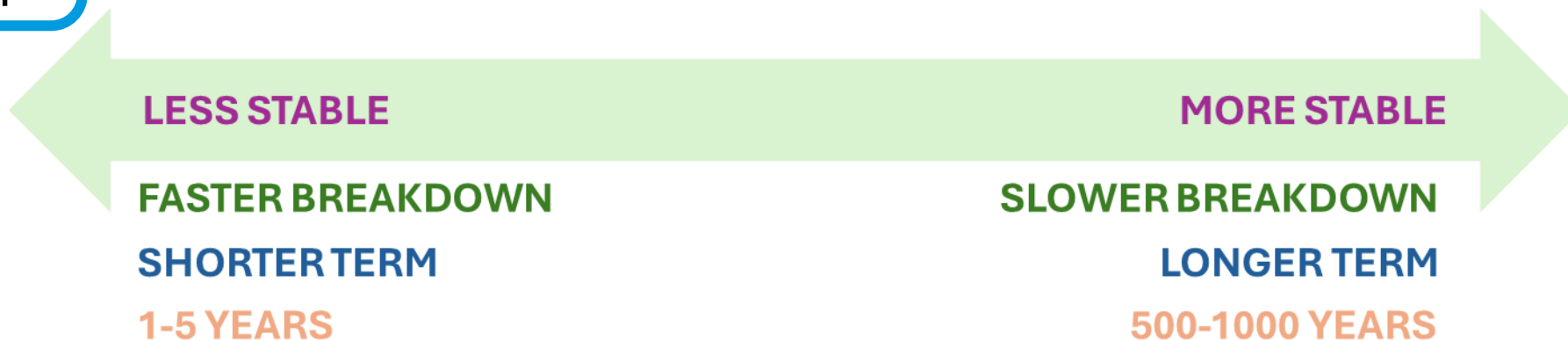


- Soil carbon (C) is an umbrella representing types (**fractions**) of C,
 - DOC, fPOM, SoPOM, MAOM
- The fractions denote level of "stability" in the soil – ability to resist degradation by biota,
 - Less stable and more easily broken down/transient vs
 - More stable and resistant to degradation.





Continuum of decomposition



Dissolved organic carbon (DOC)

- Small proportion
- Transient and C is dynamic with soil water and rainfall

Free particulate organic matter (fPOM)

- Moderate proportion
- Coarser, lighter particles of decaying material (mostly plant residues)
- Faster cycling pool

Sand & occluded particulate organic matter (SoPOM)

- Moderate proportion
- Bound to aggregates and sand particles
- Occluding refers to the "entrapment" of C
- Longer term cycling pool

Mineral associated organic matter (MAOM)

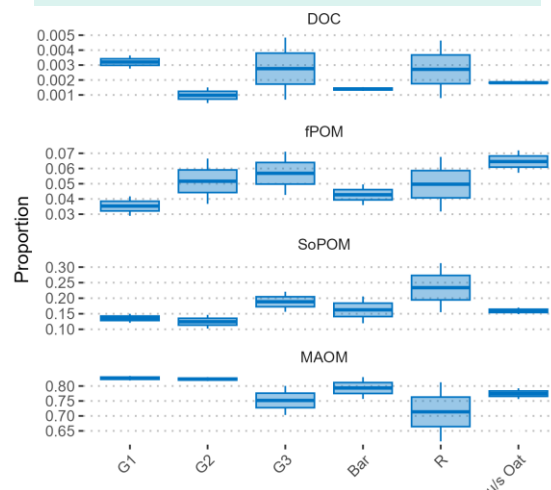
- Most abundant proportion
- Bound to silt and clay particles
- Most protected C
- Longest term cycling pool

In stocked versus stockless organic farming rotations, how and where is soil carbon stored?

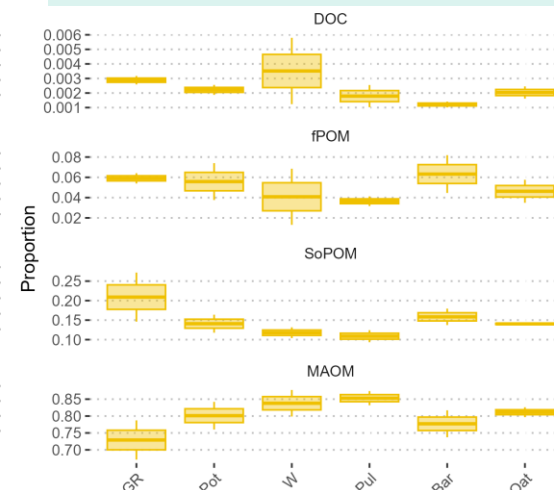
Key takeaways:

- MAOM greatest fraction as anticipated,
- MAOM greater opportunity to accumulate C in stocked rotation than stockless

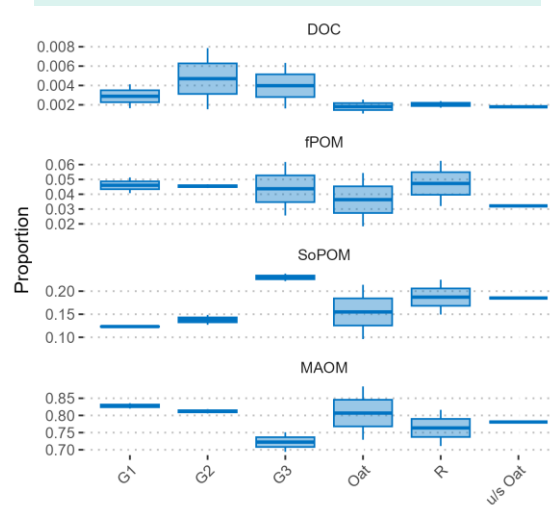
Stocked = mixed subplot A



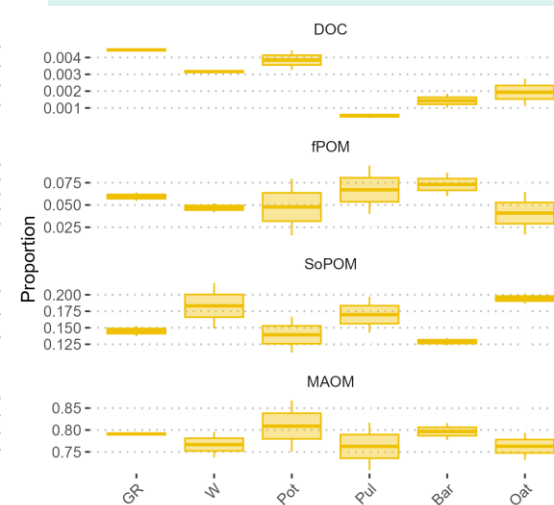
Stockless = stockless subplot A



Stocked = mixed subplot B



Stockless = stockless subplot B

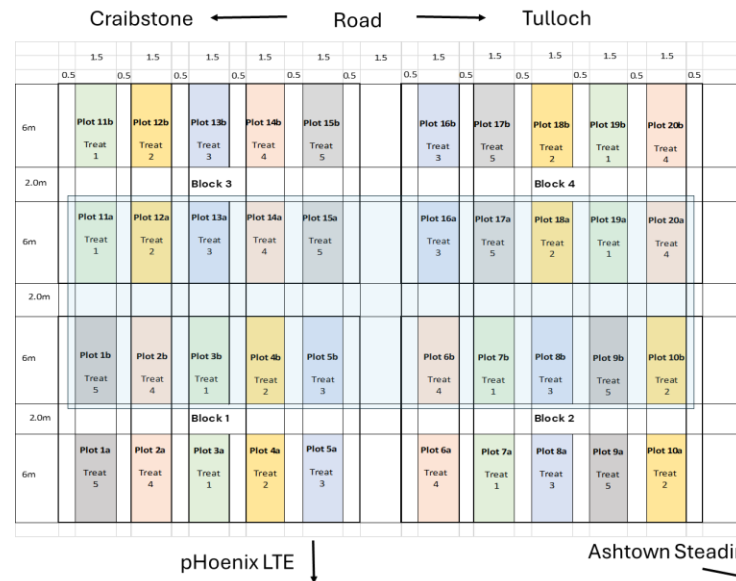
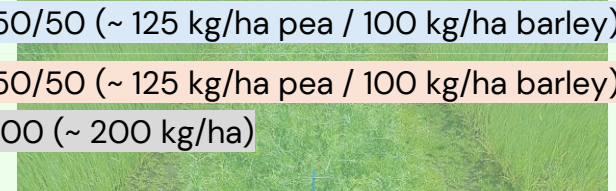
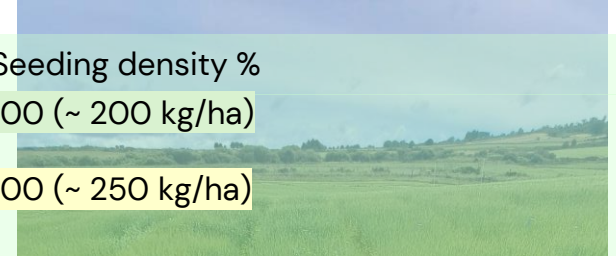


What is the effect of intercropped barley and pea (and N-fertiliser rates) on N₂O emissions?

- Grain legumes fix dinitrogen (N₂) in symbiosis with soil bacteria and use soil N sources but are often lower yielding than cereals.
- Intercropping grain legumes with cereals may be a means of increasing use efficiency of soil N.
- How will intercropping barley and peas effect N₂O emissions and crop yield with and without N-fertilisers?

Jensen, E.S., Carlsson, G. & Hauggaard-Nielsen, H. (2020). *Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis*. *Agron. Sustain. Dev.* 40, 5
<https://doi.org/10.1007/s13593-020-0607-x>

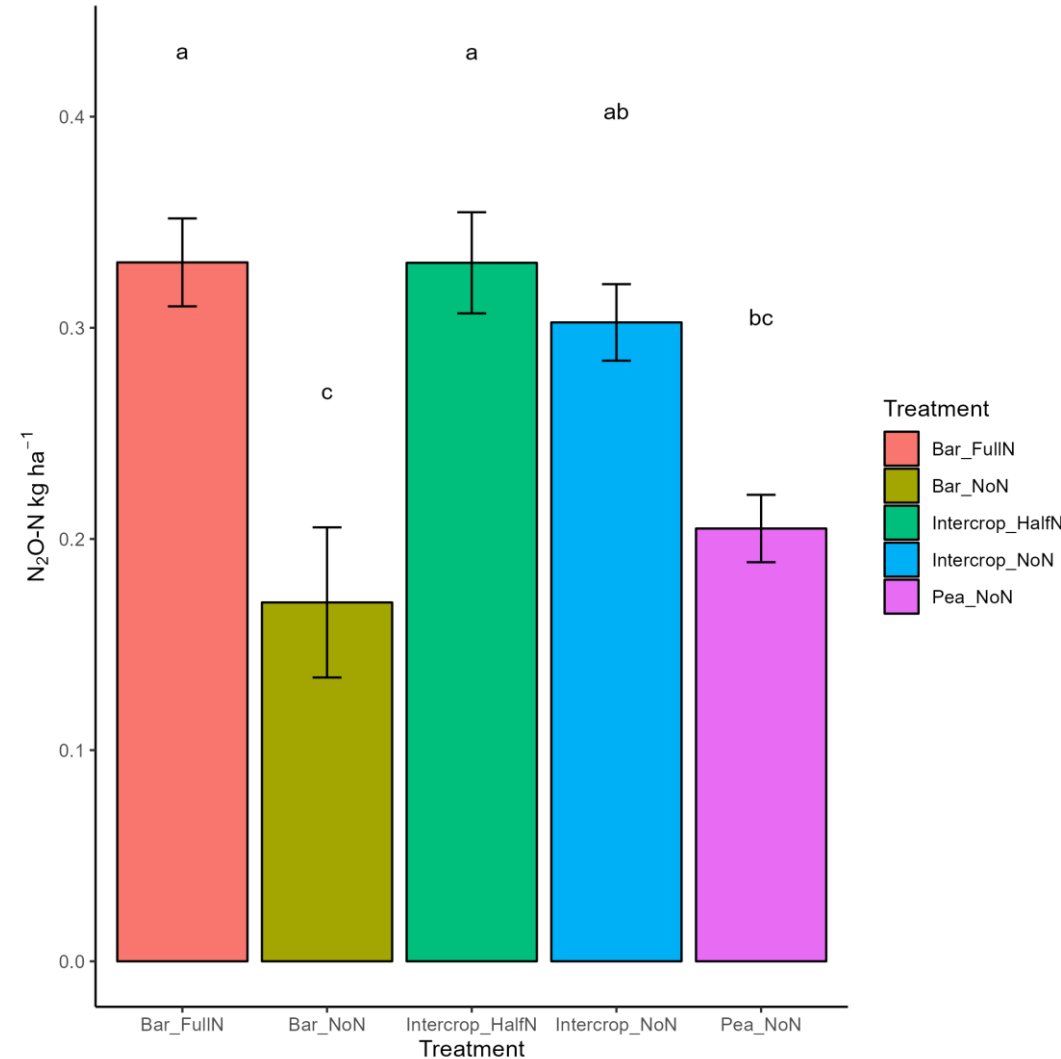
Treat No.	Sole/Intercrop	Fertilizer	Seeding density %
1	Sole crop spring barley	full N fertilization (120kg N/ha)	100 (~ 200 kg/ha)
2	Sole crop pea	no N fertilization (Zero N)	100 (~ 250 kg/ha)
3	Intercrop (barley/pea)	no N fertilization (Zero N)	50/50 (~ 125 kg/ha pea / 100 kg/ha barley)
4	Intercrop (barley pea)	half N fertilization (60kg N/ha)	50/50 (~ 125 kg/ha pea / 100 kg/ha barley)
5	Sole crop barley	no N fertilization (Zero N)	100 (~ 200 kg/ha)



What is the effect of intercropped barley and wheat (and N-fertiliser rates) on nitrous oxide emissions?

Key takeaways:

- Intercropping has similar net N_2O emissions as barley full-N, legumes likely providing sufficient N for yield
- Complex below-ground interactions TBD
- Yield TBD



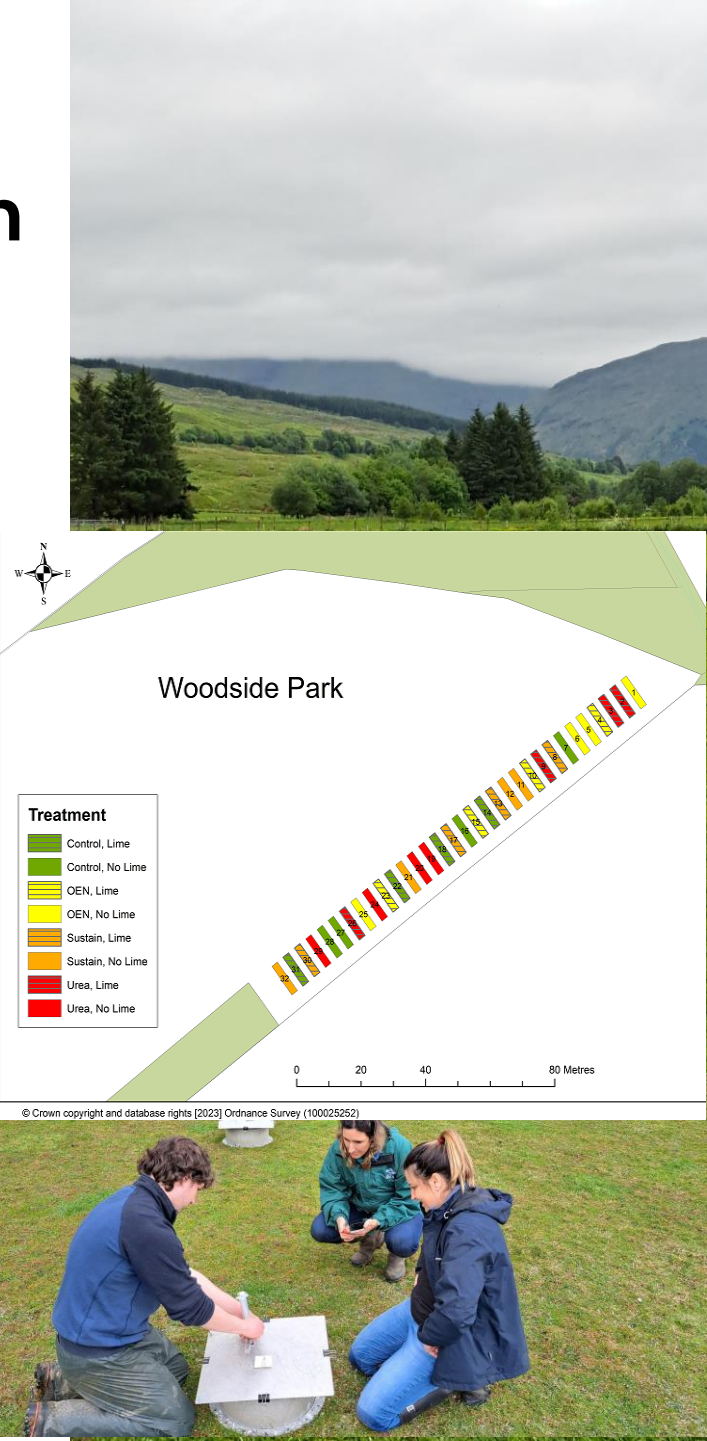
Nitrous Oxide Emission trial, Kirkton, Crianlarich

In a livestock grassland system, what are the effects of nitrification and urease inhibiting mechanisms in N-fertilisers on N₂O emissions?

- N-fertilisers used to meet 48% of the total global food demand,
- N-fertiliser key source of GHG (N₂O) emissions and nitrate leaching,
- Nitrification and urease inhibitors in N-fertilisers = mitigation tools.

Byrne, M.P., Tobin, J.T., Forrestal, P.J., Danaher, M., *et al.*, (2020). Urease and nitrification inhibitors—As mitigation tools for greenhouse gas emissions in sustainable dairy systems: A review. *Sustainability*, 12(15), p.6018.

Treatment	Lime t/ha	N Application (April/May) Kg N/ha	summary
1.Control	0	0	control, no lime
2. Urea	0	150	urea, no lime
3. Urea plus urease inhibitor	0	150	urea, urease inhibitor, no lime
4. Urea plus nitrification inhibitor	0	150	urea, nitrification inhibitor, with lime
5 Control	10	0	control, with lime
6. Urea	10	150	urea, with lime
7. Urea plus urease inhibitor	10	150	urea, urease inhibitor, with lime
8. Urea plus nitrification inhibitor	10	150	urea, nitrification inhibitor, with lime



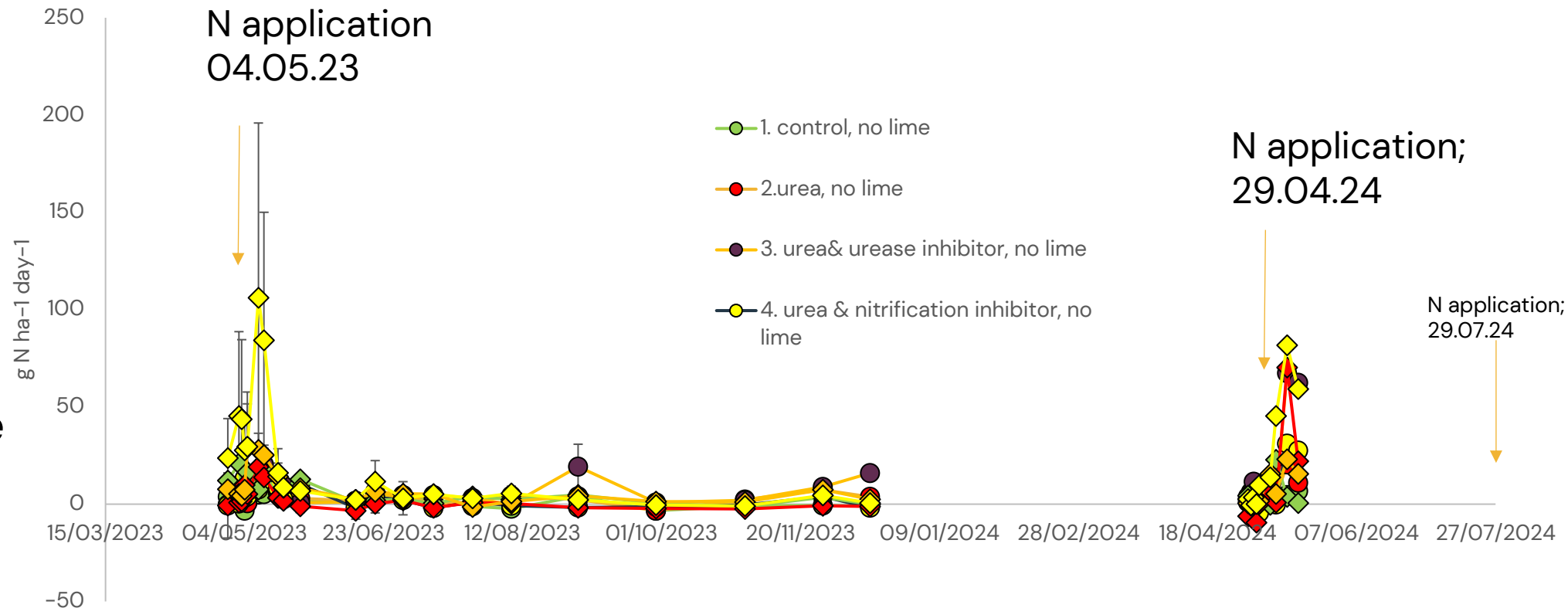
**Nitrous
Oxide
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Key takeaways:

- Complex drivers of N₂O
- Rainfall, temp, animal waste around fertilising time have huge impacts



Implications of field trials

- Major areas of complexity in applications of land use management for meeting net zero targets,
- Unfortunately, not simple but always more being revealed!

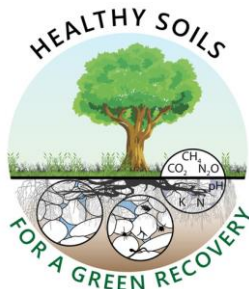
Acknowledgements



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