

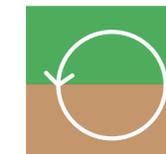
Strategies to build soil carbon stocks



Dr. Ashish Malik, Chancellor's Fellow



THE UNIVERSITY
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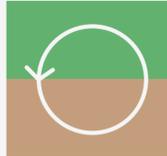


Microbial
Biogeochemistry
Lab

Acknowledgements



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Microbial Biogeochemistry Lab



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@ashish-malik



Funding



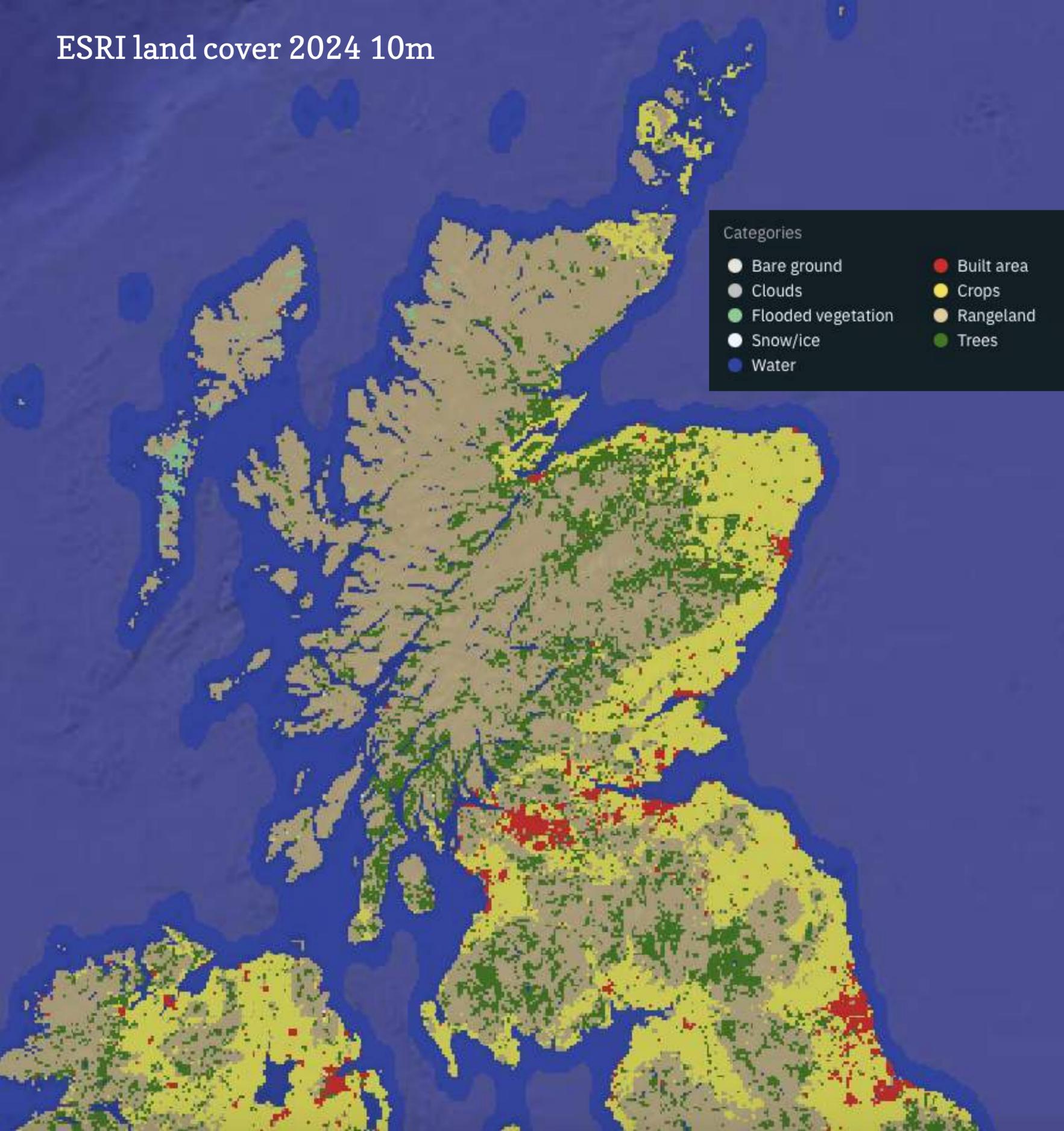
International Human Frontier Science Program Organization



Office of Science



ESRI land cover 2024 10m



Strategies to build soil carbon stocks



Scotland's Draft Climate Change Plan: 2026-2040



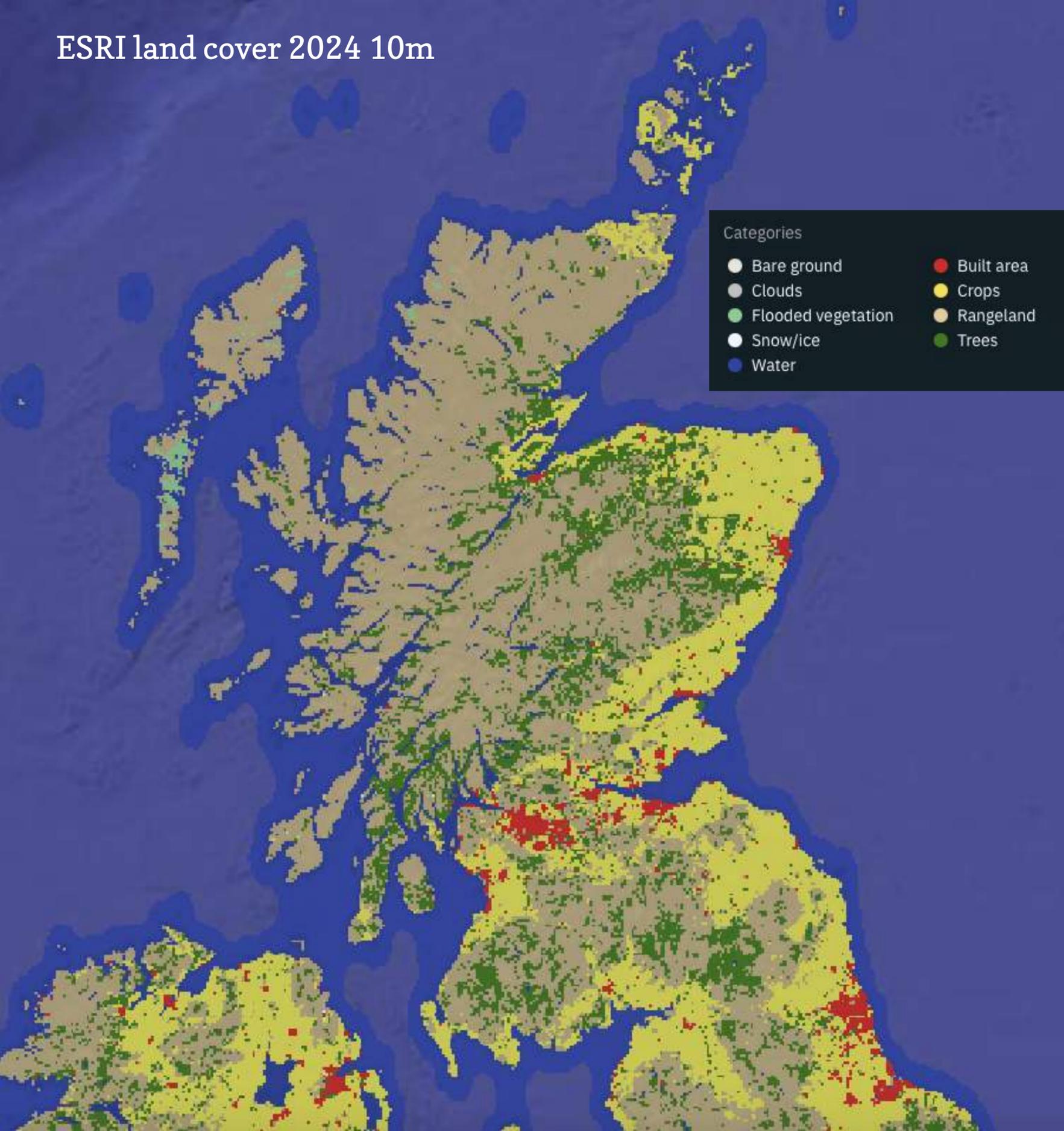
November 2025



The word 'soil' doesn't
feature once in Scotland's
thirty-one-page draft
Climate Change Plan

Professor Neil Metcalfe
BES Scottish Policy Group Chair

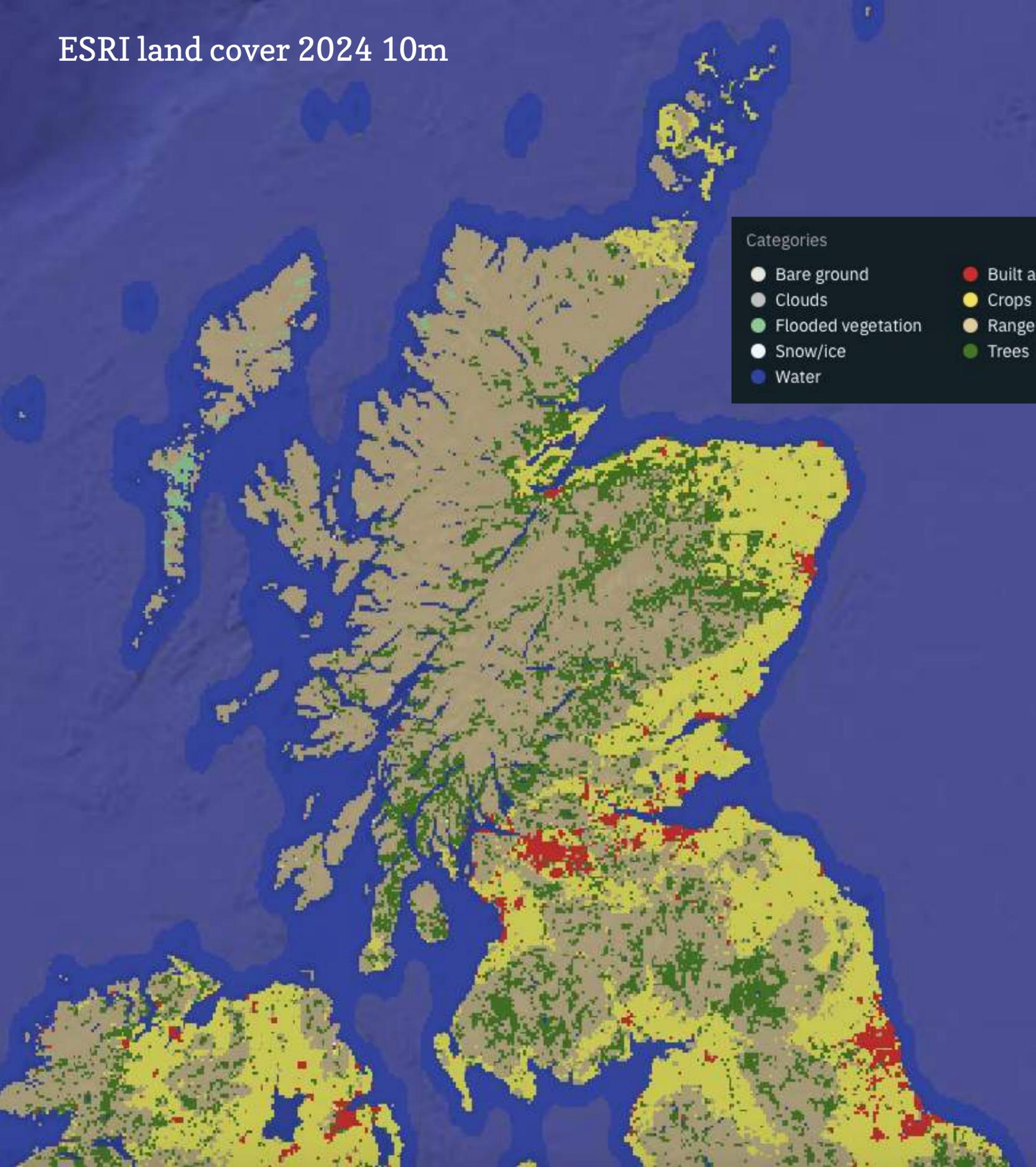
ESRI land cover 2024 10m



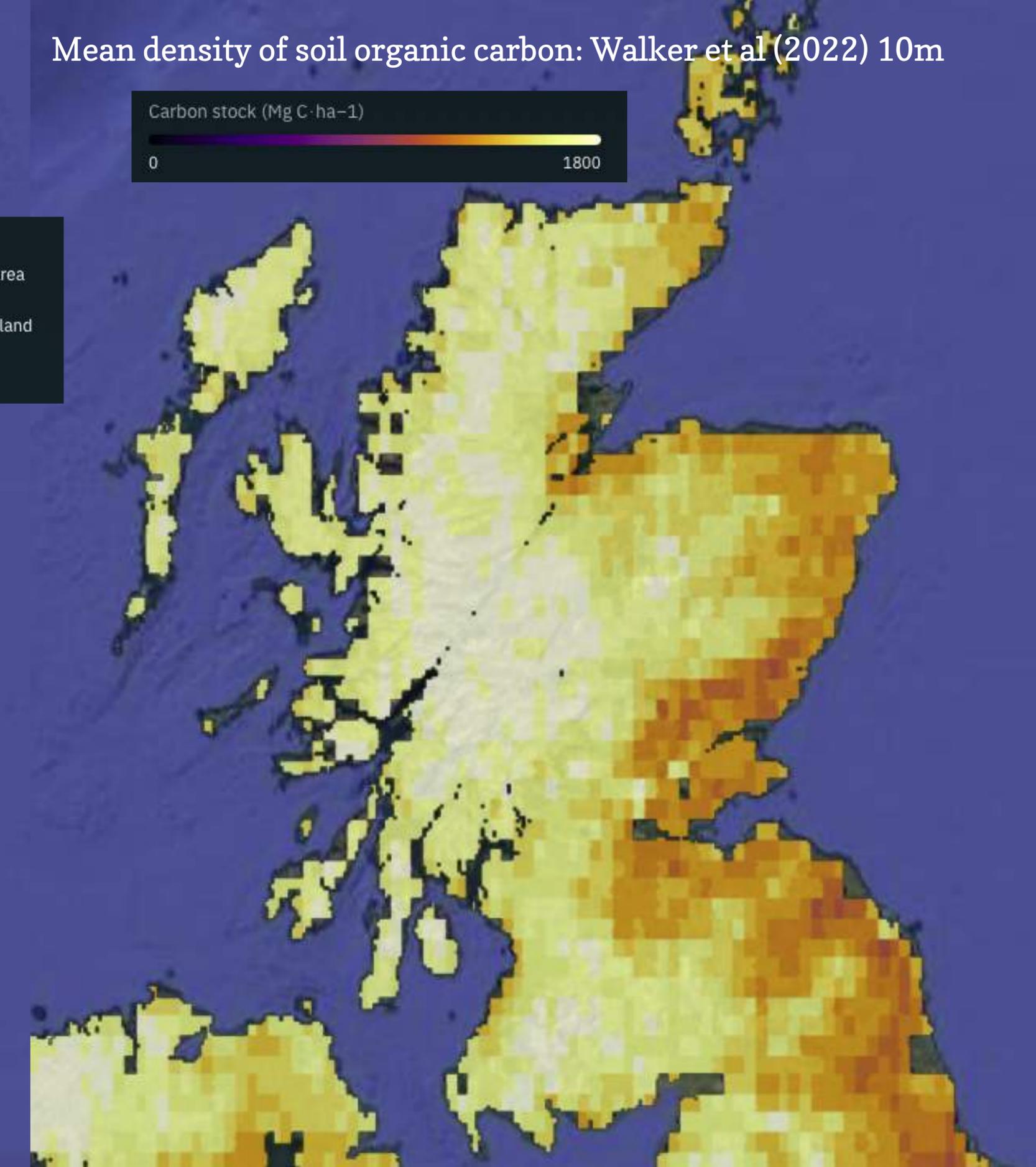
Strategies to build soil carbon stocks



ESRI land cover 2024 10m



Mean density of soil organic carbon: Walker et al (2022) 10m



Carbon stock (Mg C · ha⁻¹)

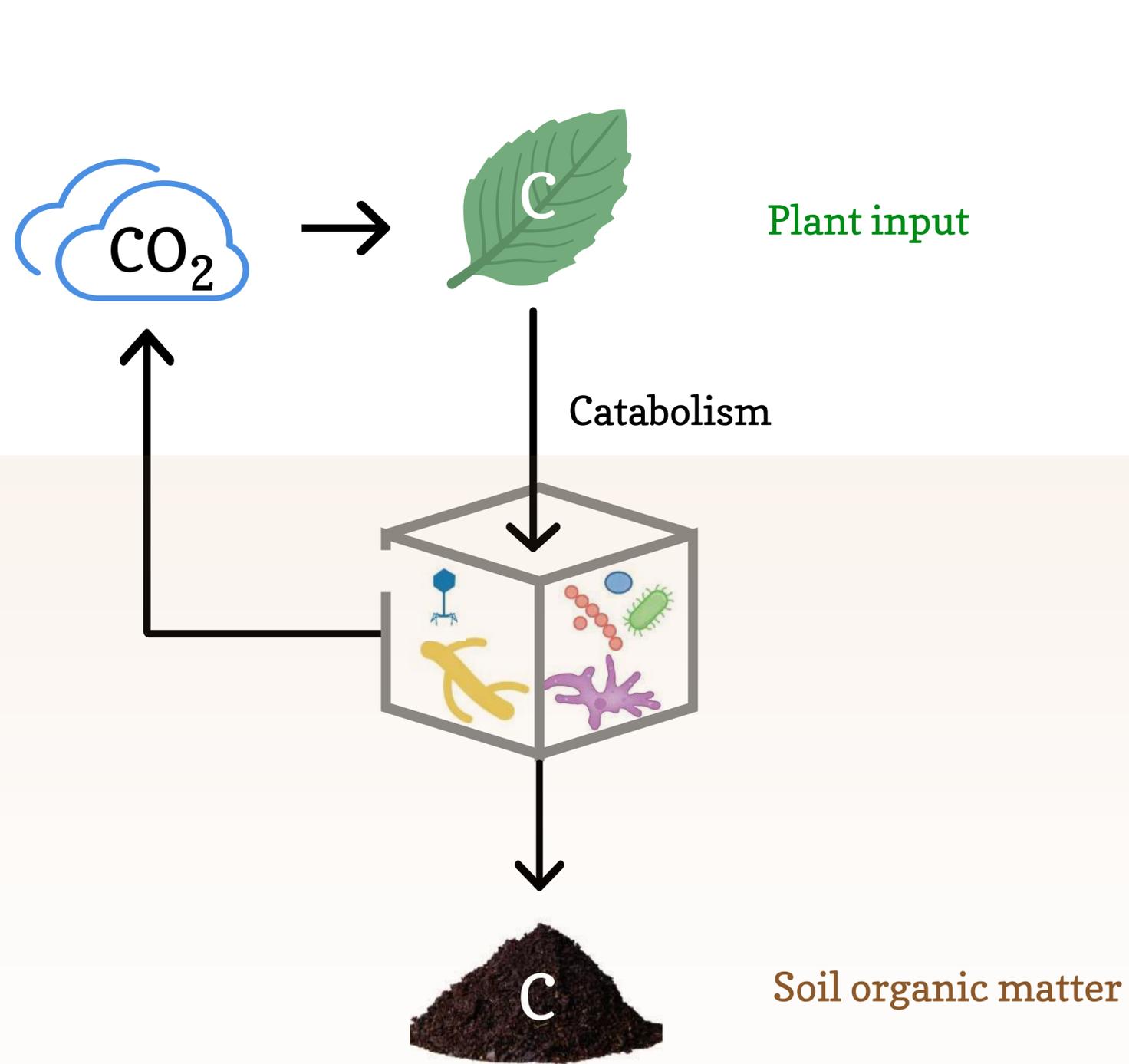
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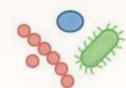
1800

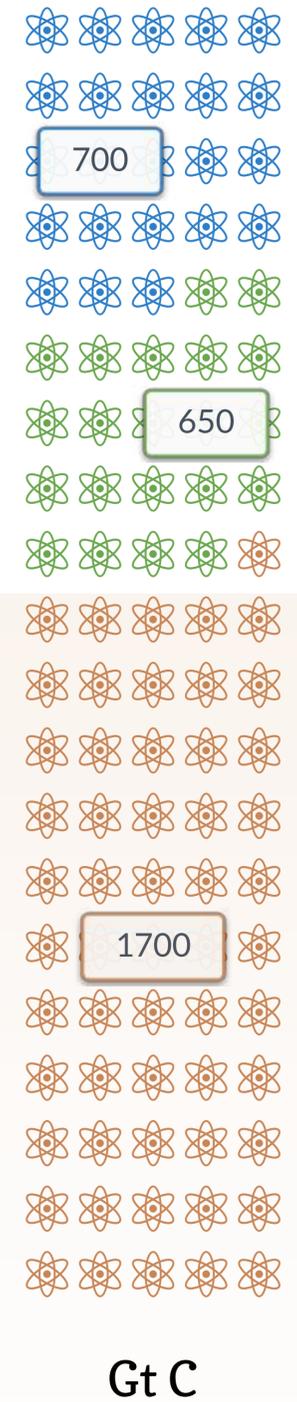
Categories

- Bare ground
- Clouds
- Flooded vegetation
- Snow/ice
- Water
- Built area
- Crops
- Rangeland
- Trees

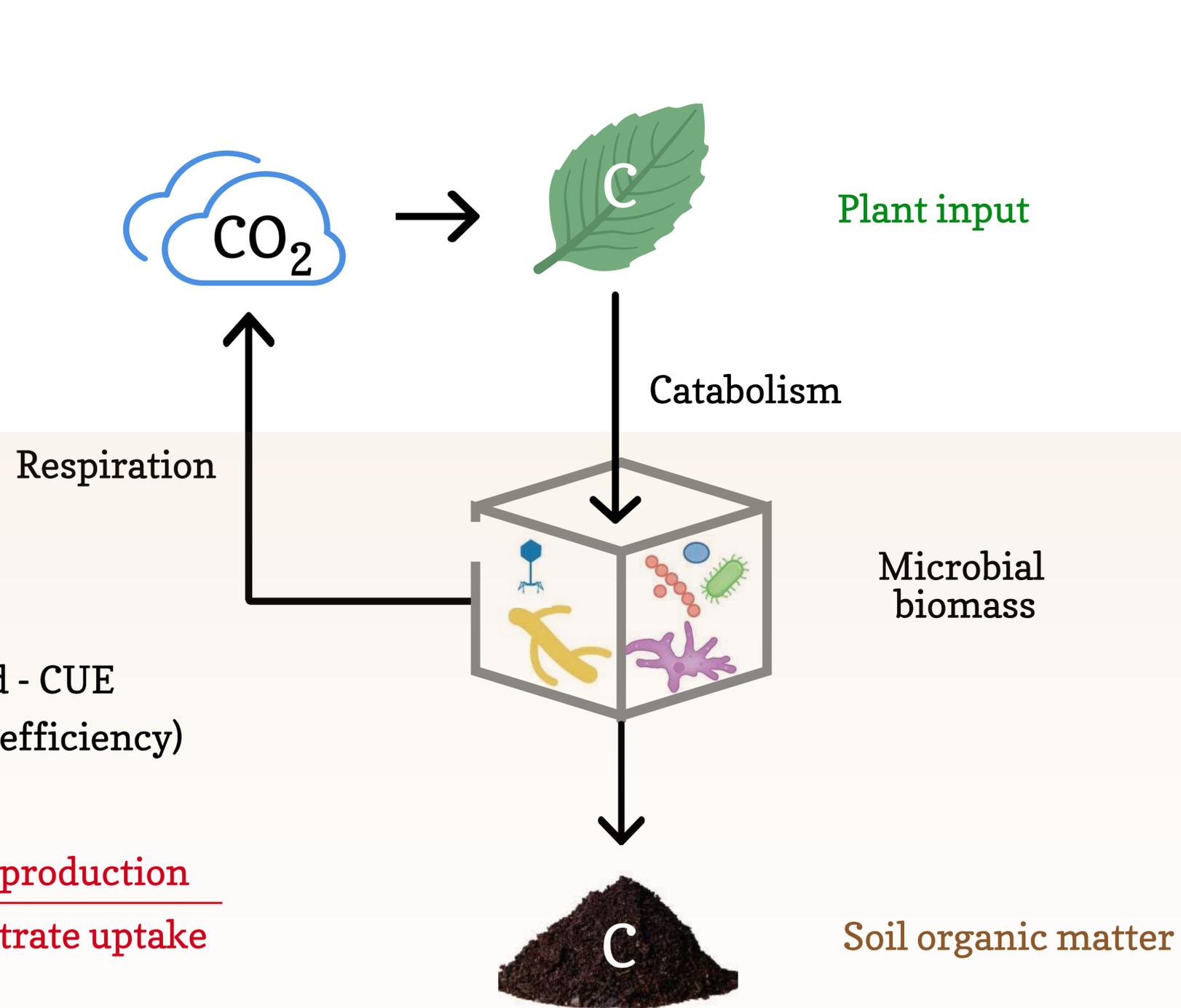
How microbes impact soil carbon cycling



-  Bacteria
-  Virus
-  Fungi
-  Protist

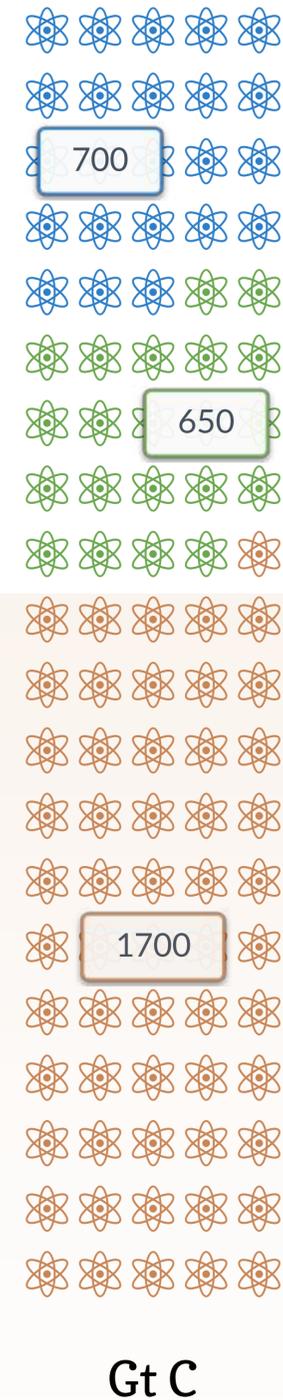


How microbes impact soil carbon cycling

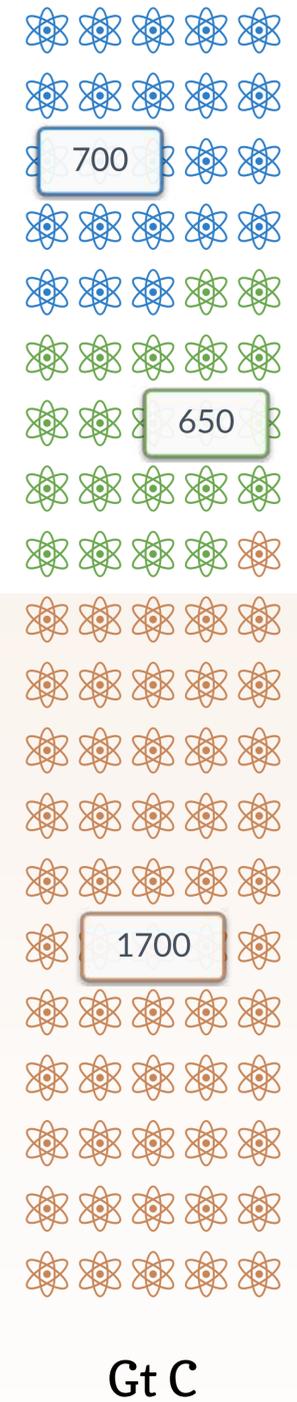
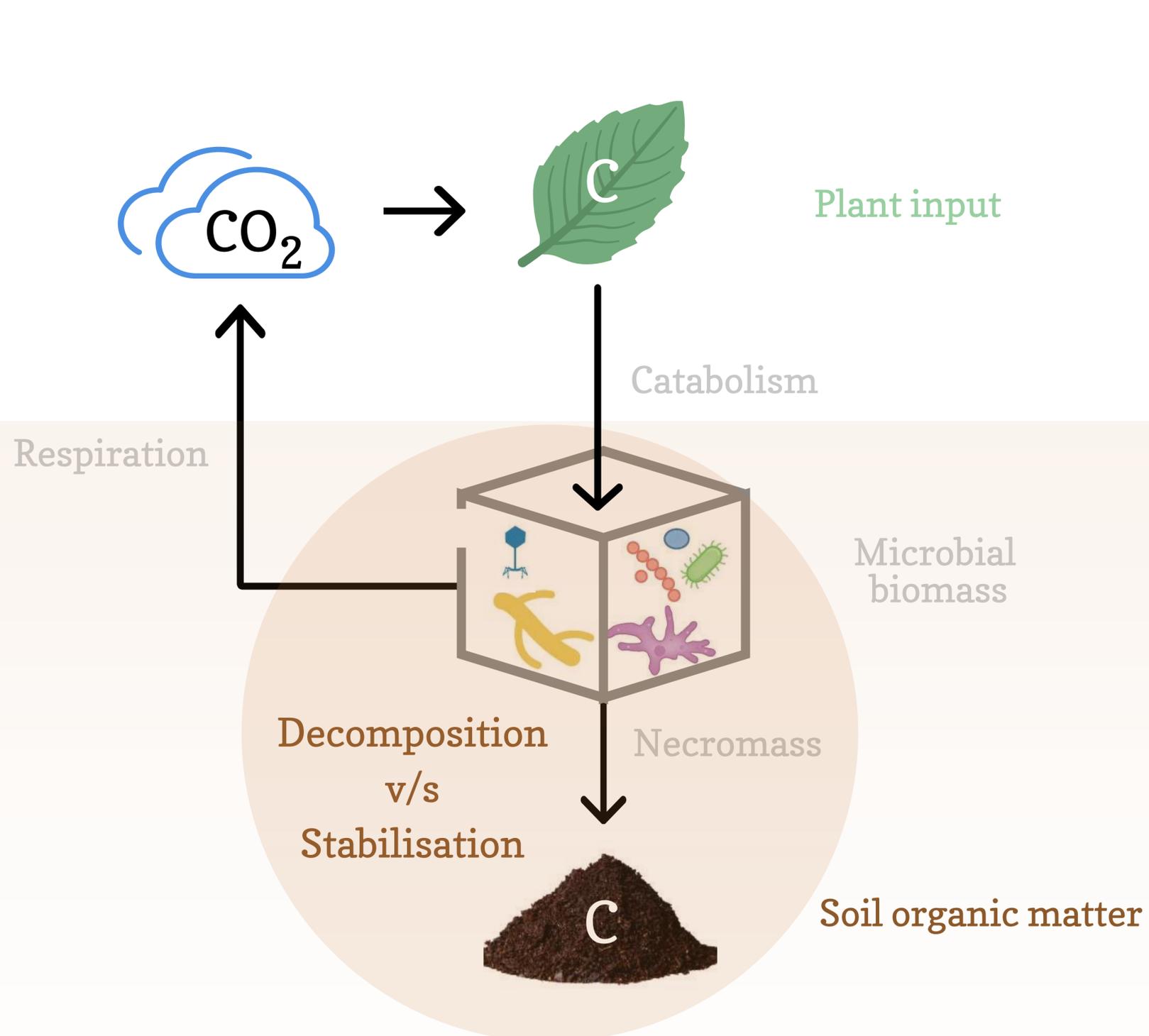


Σ Growth yield - CUE
(Carbon use efficiency)

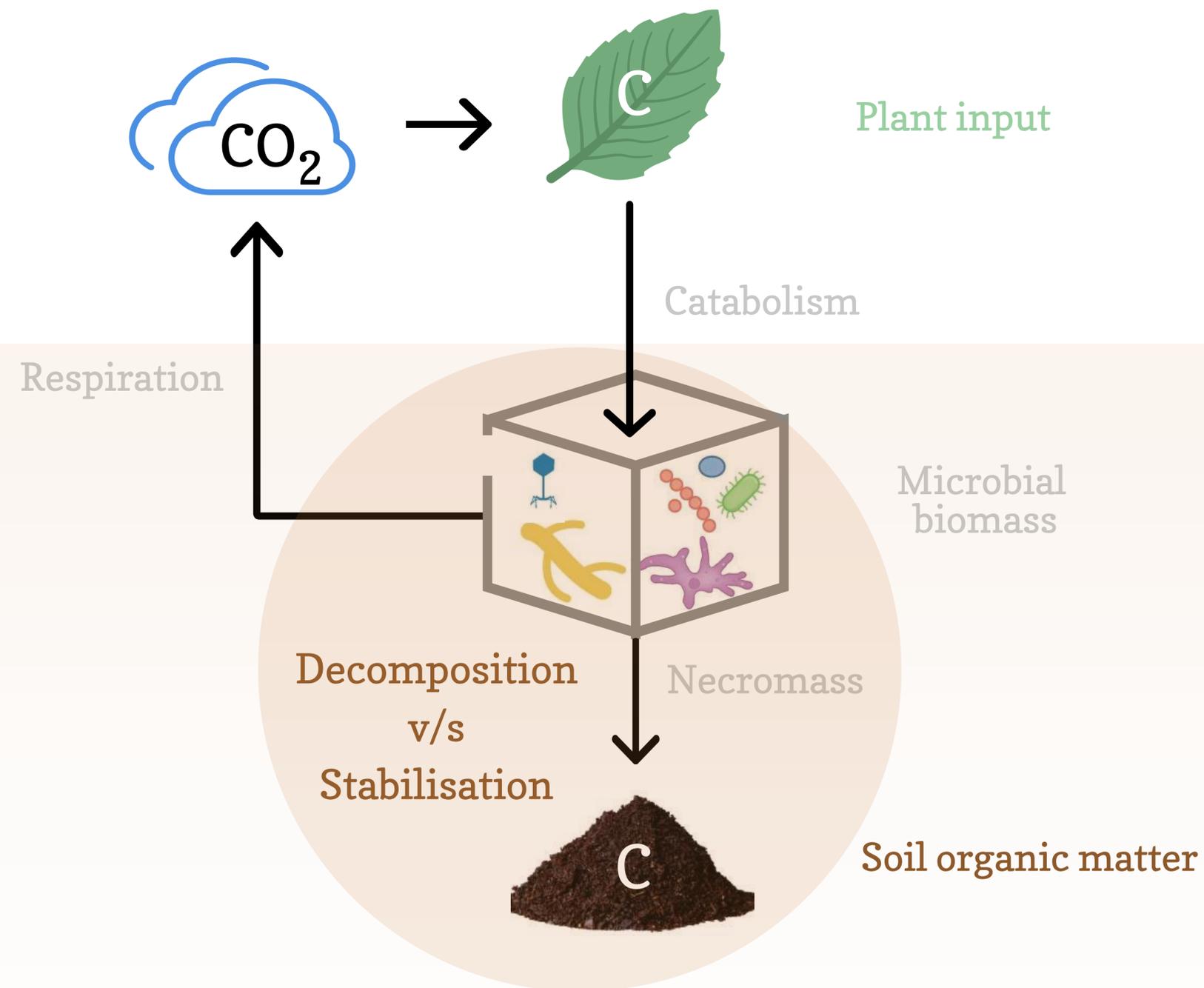
$$\text{CUE} = \frac{\text{Biomass production}}{\text{Total substrate uptake}}$$



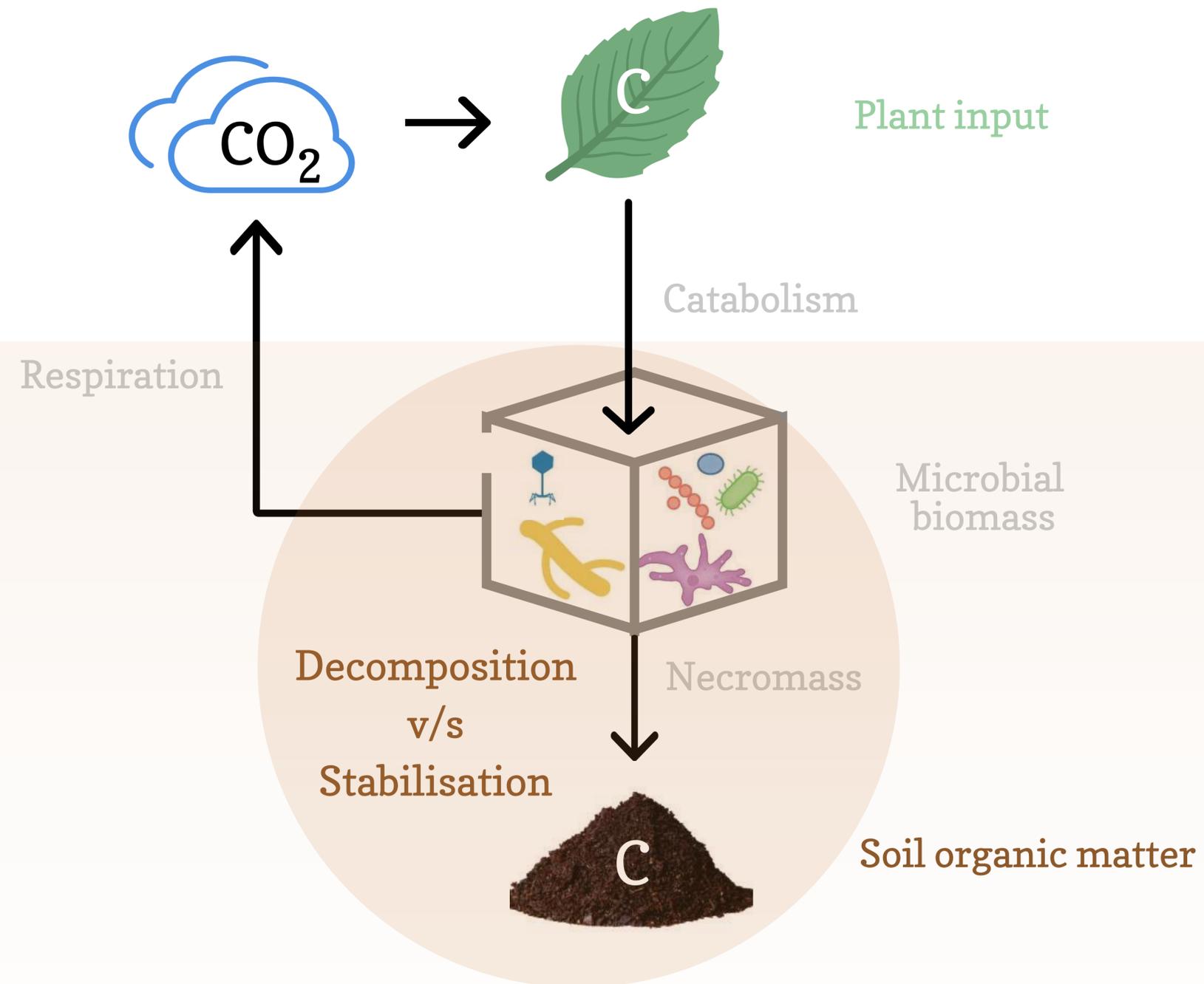
Microbes act as gatekeepers of soil-atmosphere carbon exchange



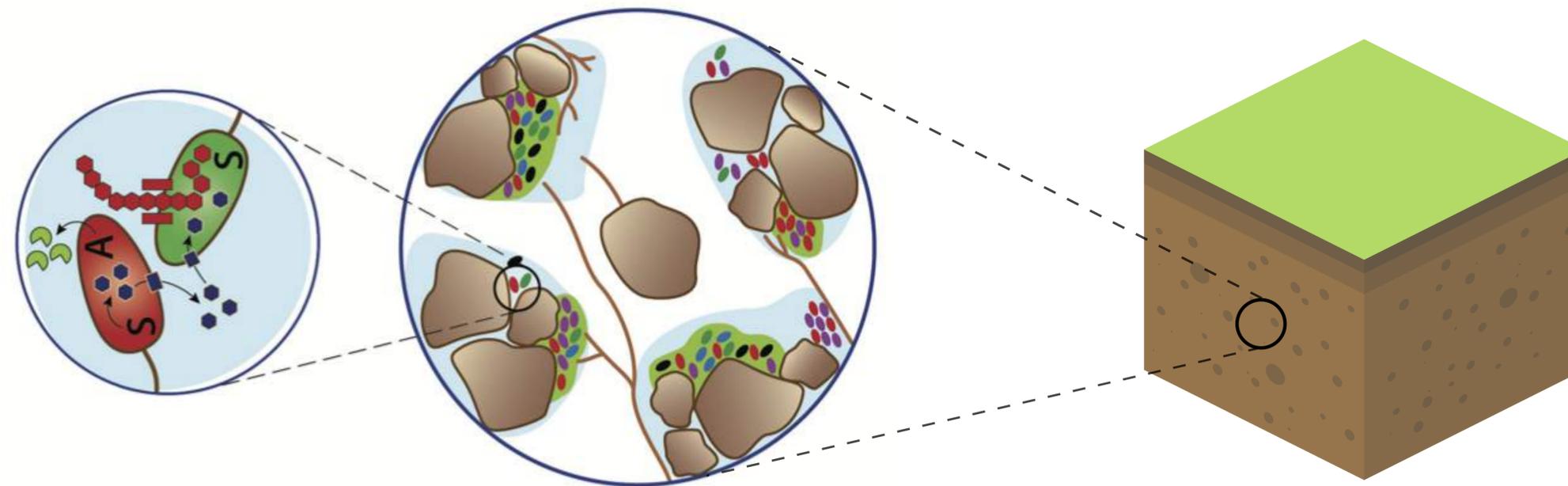
Soil carbon balance determined by microbial processes



Soil carbon balance determined by microbial processes



Vision: use information on physiological response of microbes in a changing environment to reliably measure and predict changes in soil carbon



Ecophysiology

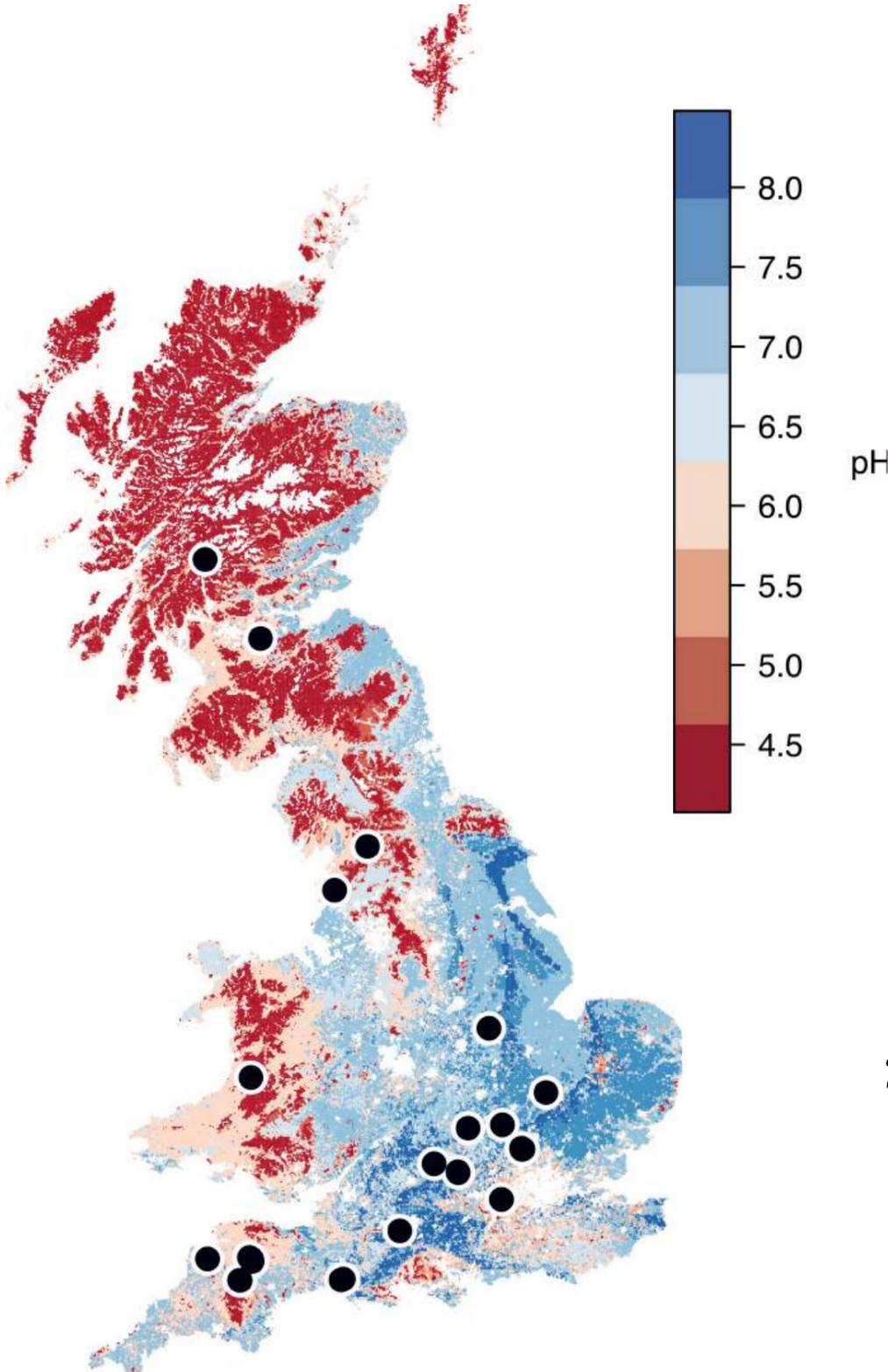
Biogeochemistry

Ecosystem science



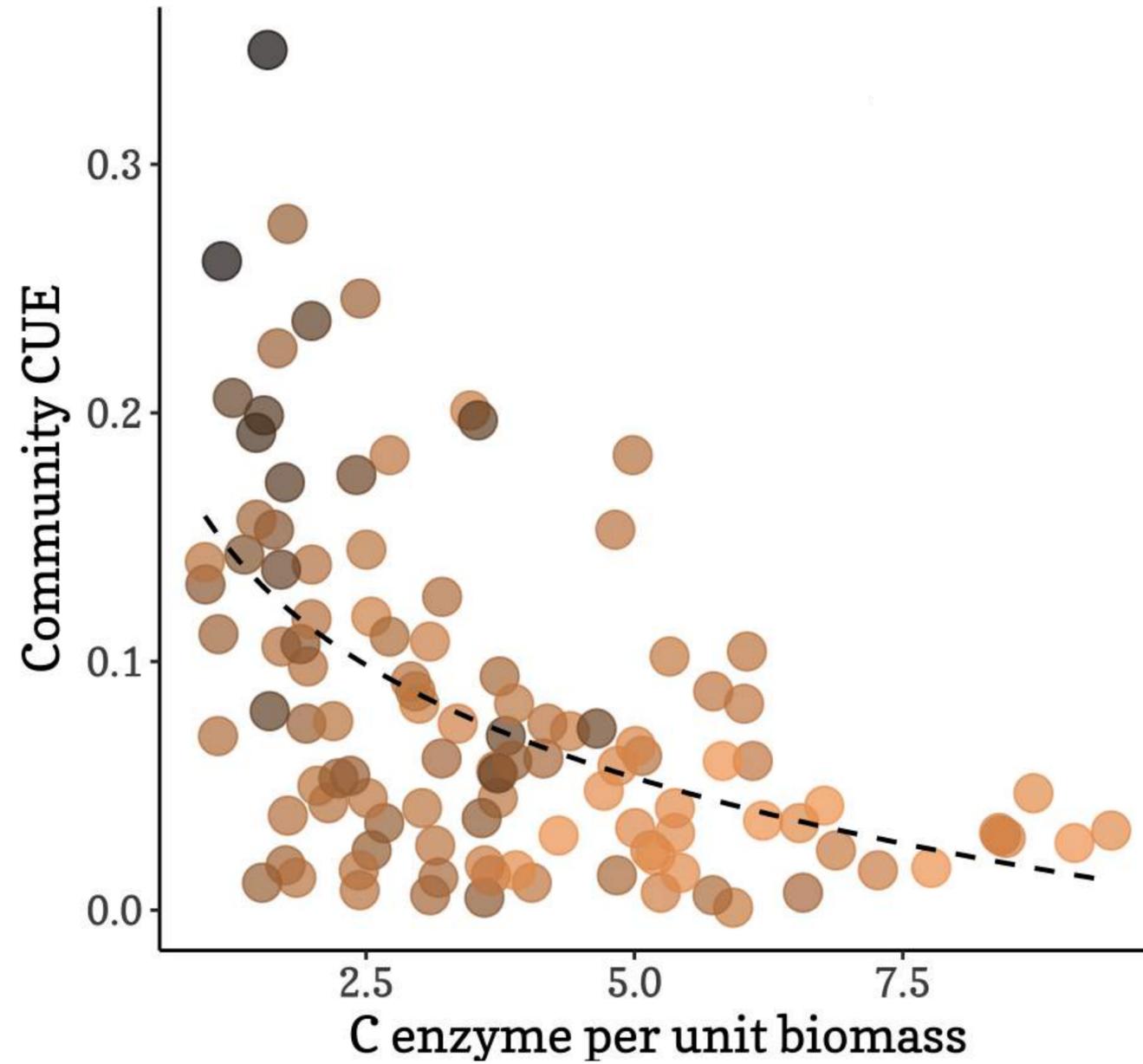
Loss of 133 Gt C due to agricultural land use
=
C lost from vegetation due to deforestation

Microbial ecophysiology linked to carbon cycling in soils across land use gradients

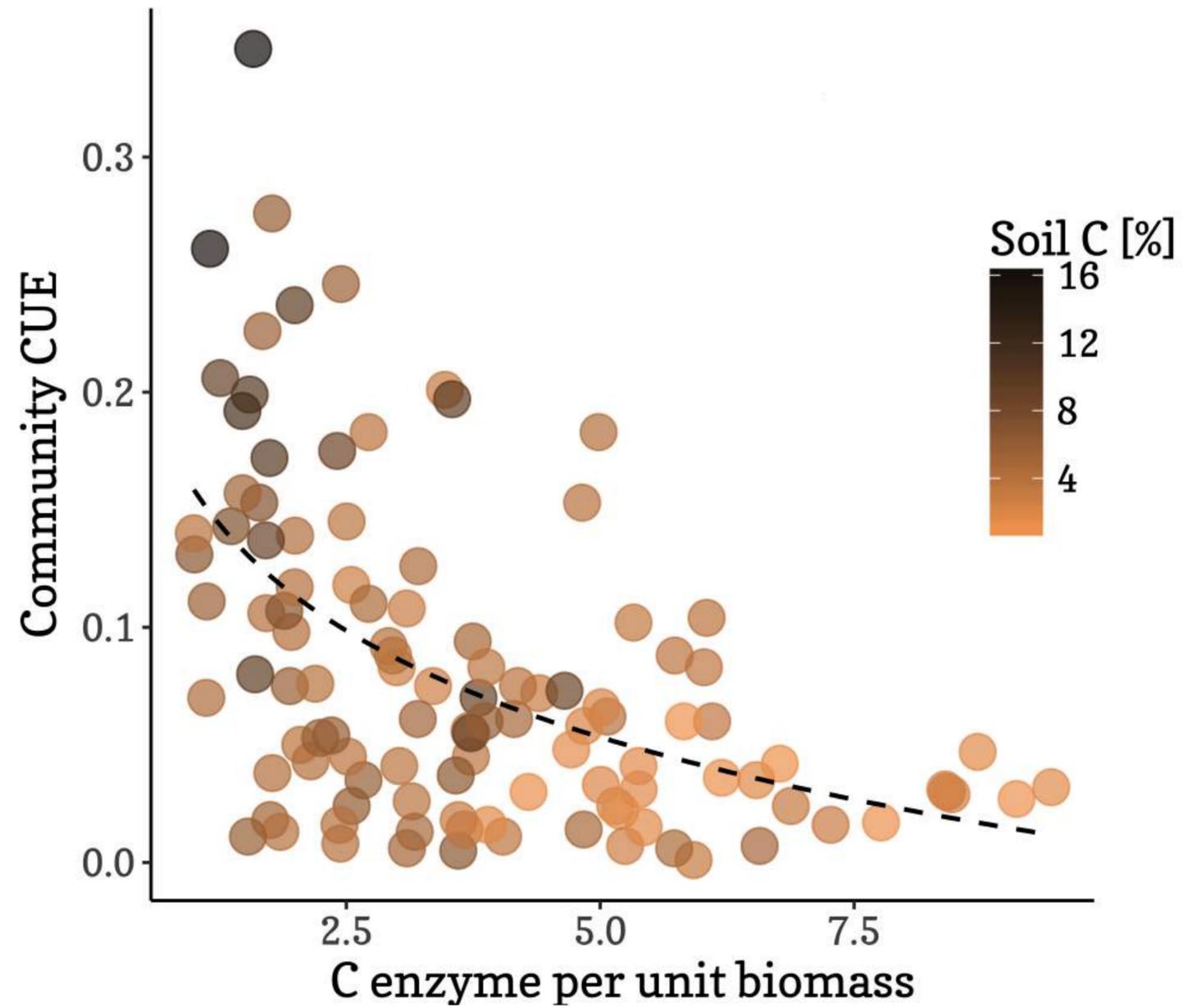


28 sites with paired contrasts

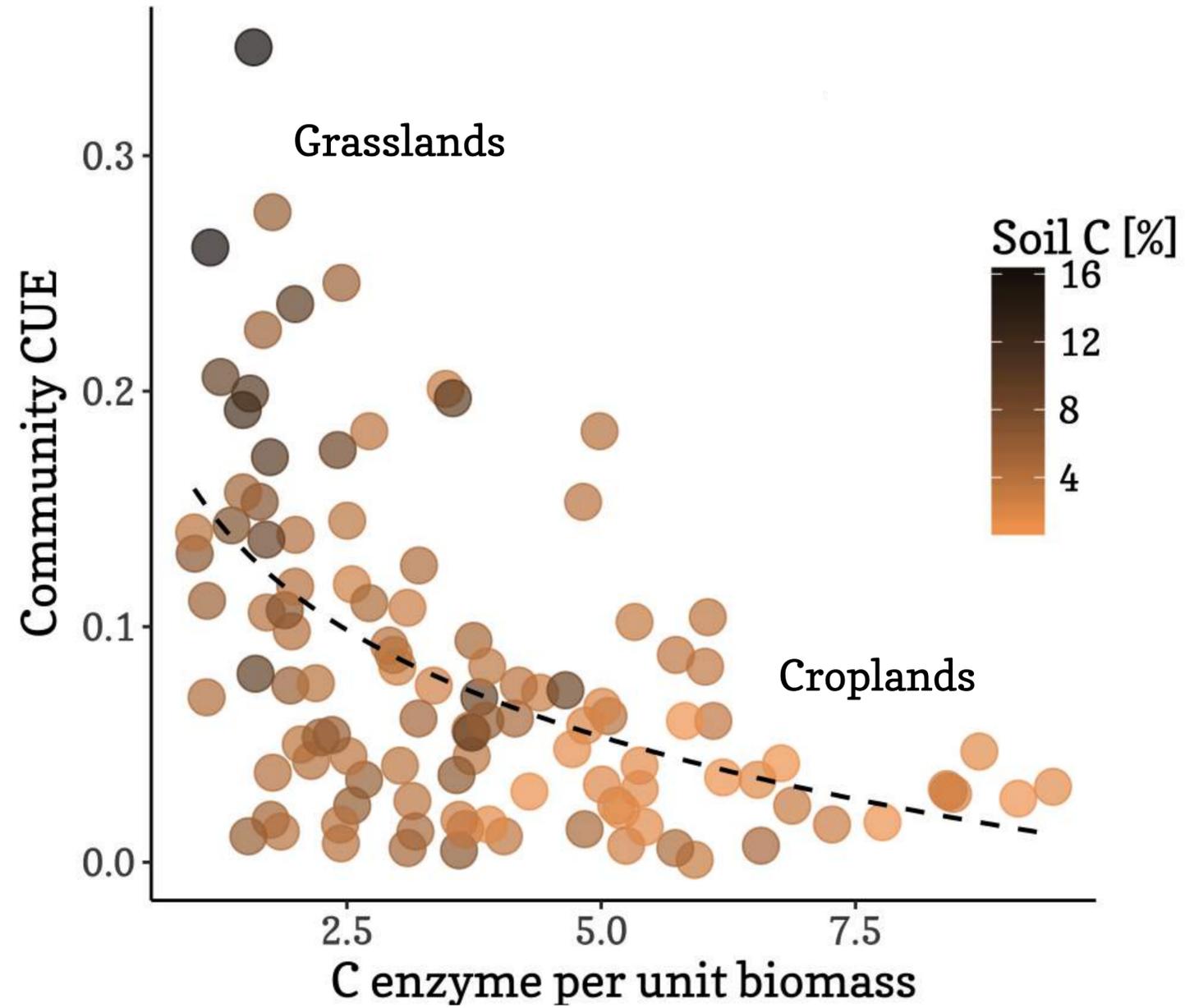
Increased investment in resource acquisition was linked to reduced CUE - carbon use efficiency



Microbial CUE differences were linked to soil organic carbon loss/gain

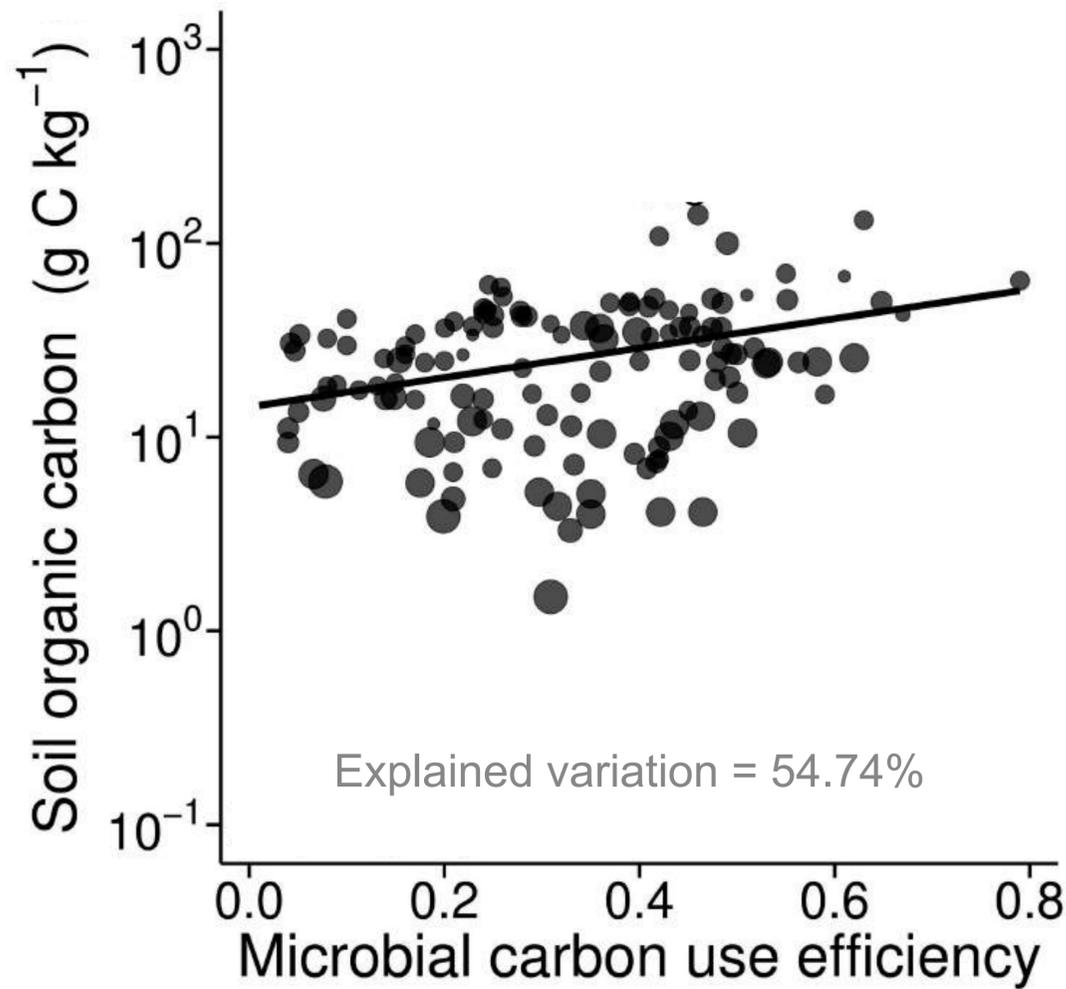


Microbial CUE differences were linked to soil organic carbon loss/gain

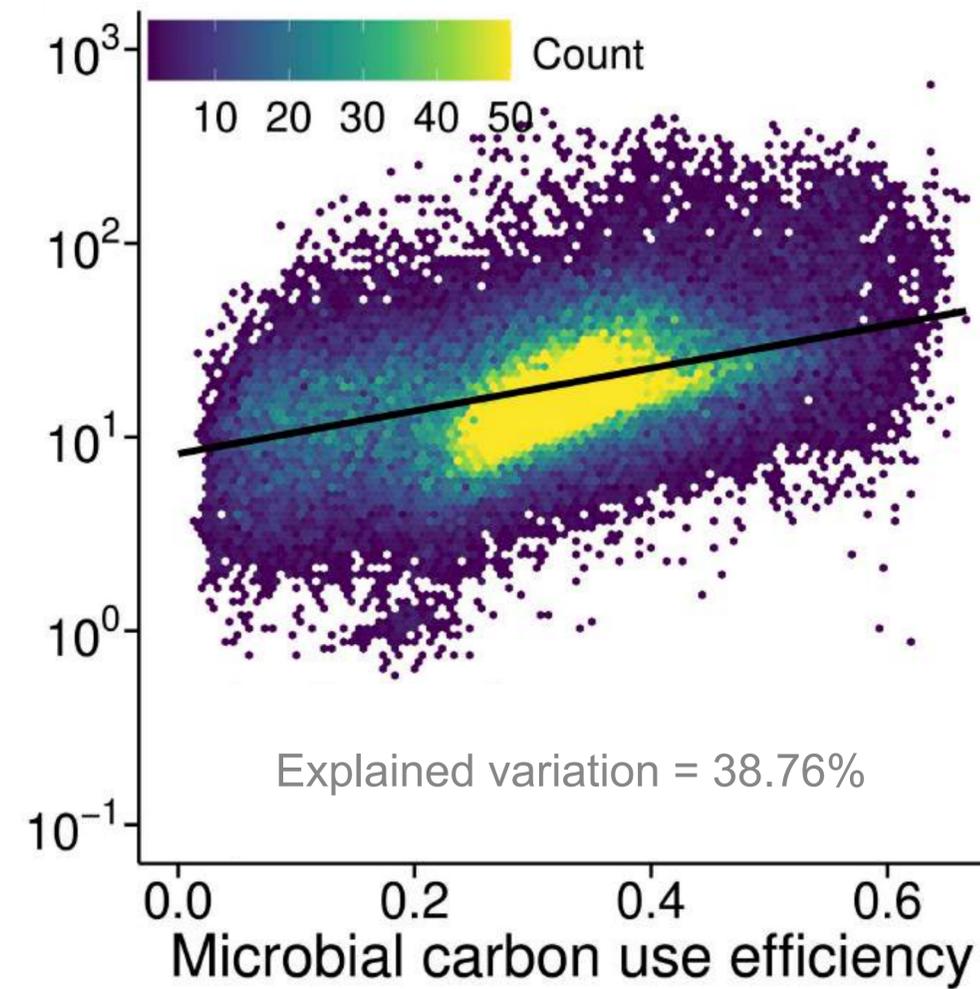


Microbial carbon use efficiency (CUE) promotes soil carbon storage at the global scale

Meta-analysis of 132 measurements

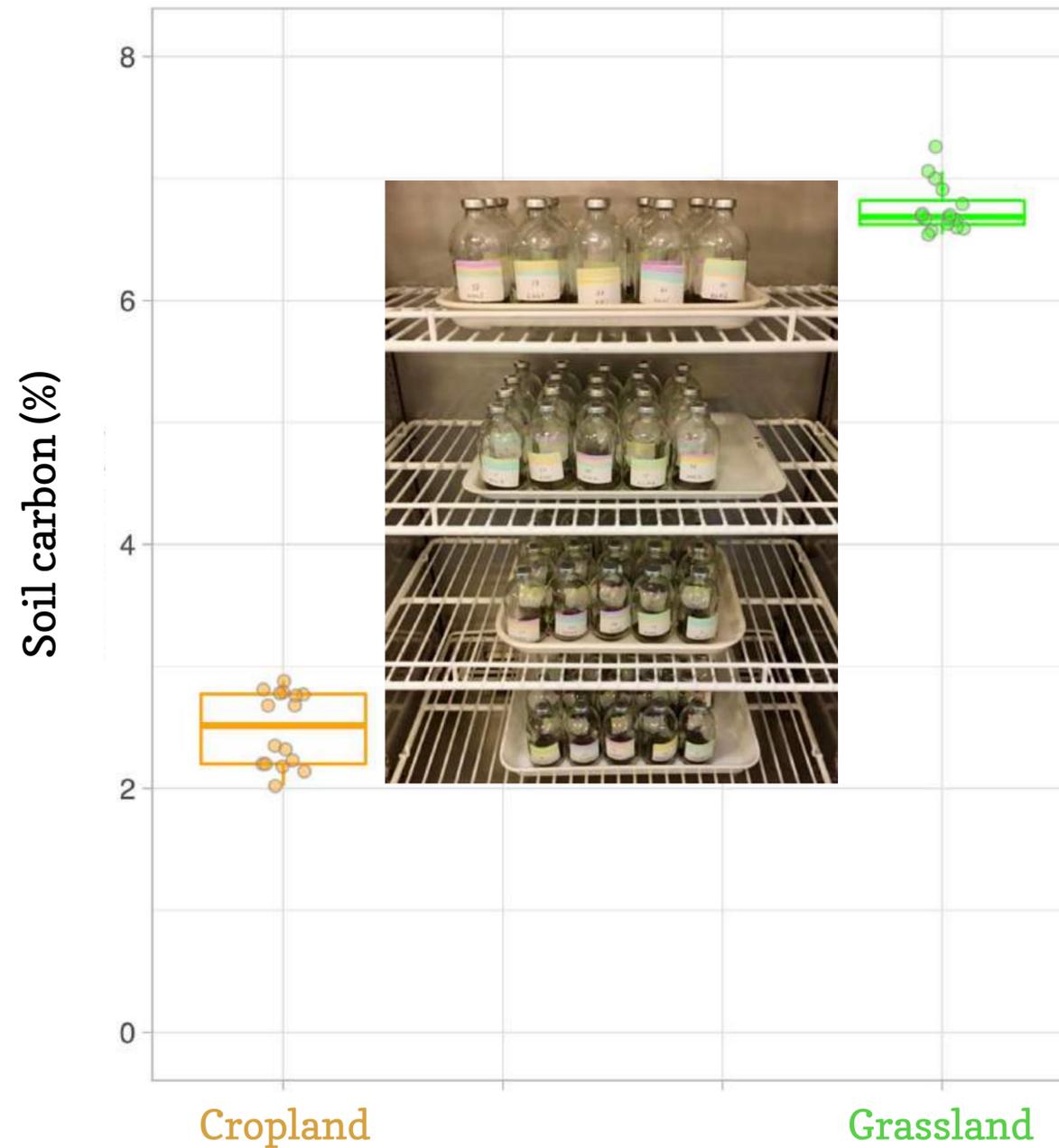


Data assimilation using a microbial model with 57k global SOC profiles



Can we recruit grassland microbes to help restore soil carbon in degraded soils?

Soil carbon build up after 8 months in sterilised soils with microbial inoculation



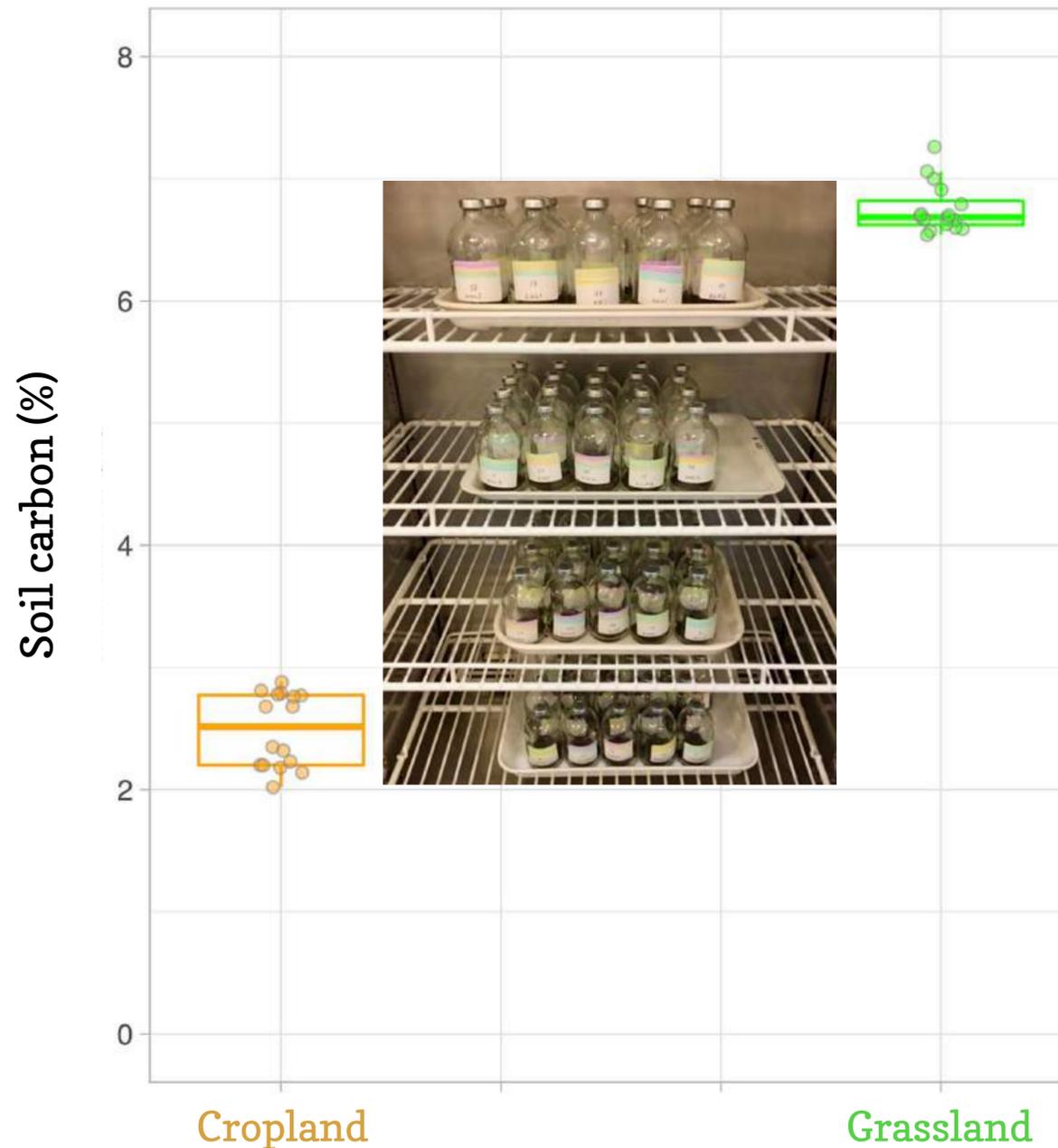
Dr. Lisa Cole
Daphne Jackson
Trust Fellow

Can we recruit grassland microbes to help restore soil carbon in degraded soils?



Dr. Lisa Cole
Daphne Jackson
Trust Fellow

Soil carbon build up after 8 months in
sterilised soils with microbial inoculation



Probiotics hypothesis:

Inoculum matters in building soil carbon

Microbes from grassland soil with high CUE assemble and builds soil carbon in cropland soil

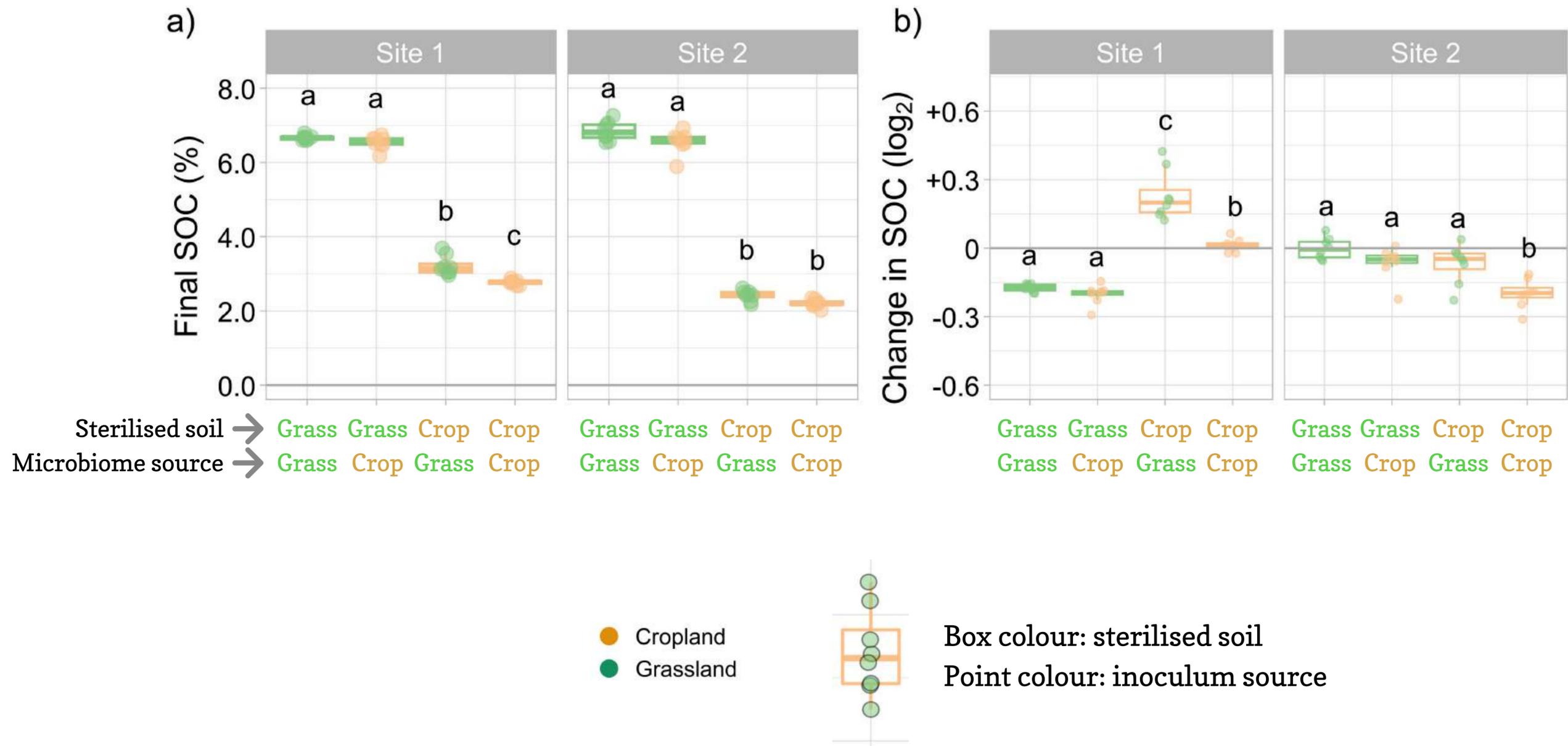
Prebiotics hypothesis:

Soil conditions matter in building soil carbon

Good soil properties of grassland soil select for microbes with high CUE that build soil carbon, irrespective of the inoculum source

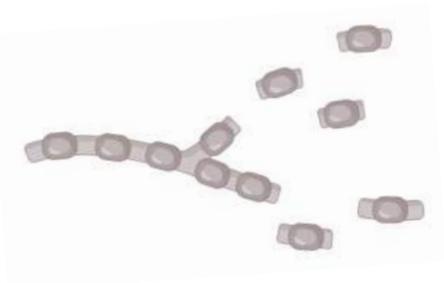
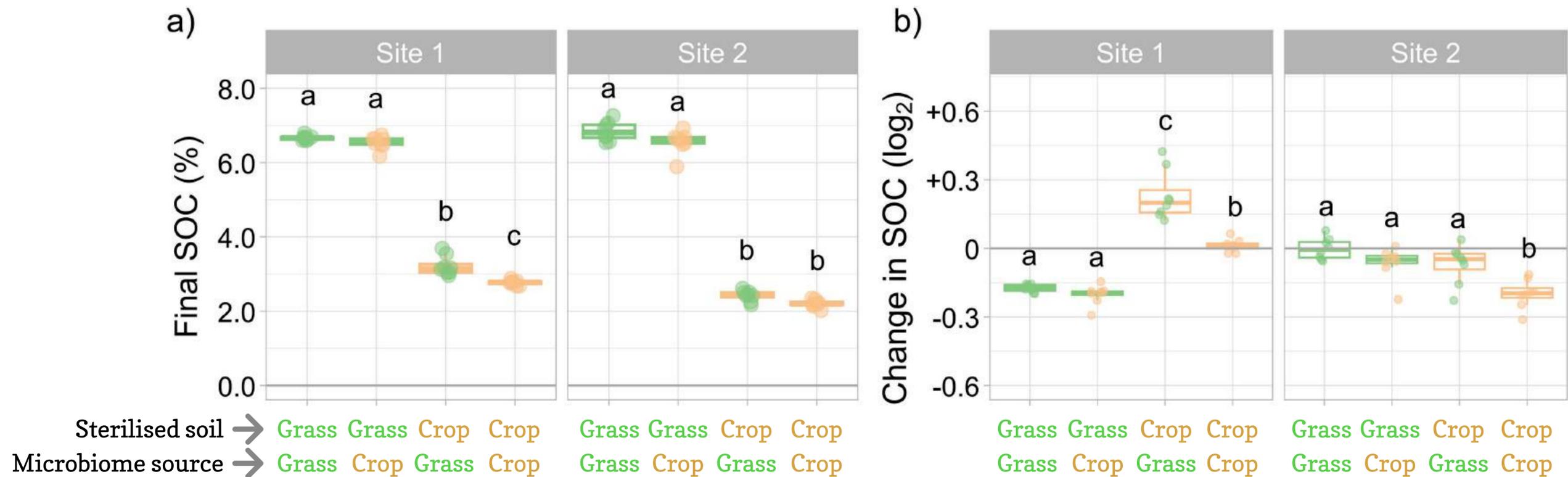
Introduction of grassland inoculum into cropland soils resulted in better SOC outcomes

Soil carbon build up after 8 months in sterilised soils with microbial inoculation



Introduction of grassland inoculum into cropland soils resulted in better SOC outcomes

Soil carbon build up after 8 months in sterilised soils with microbial inoculation



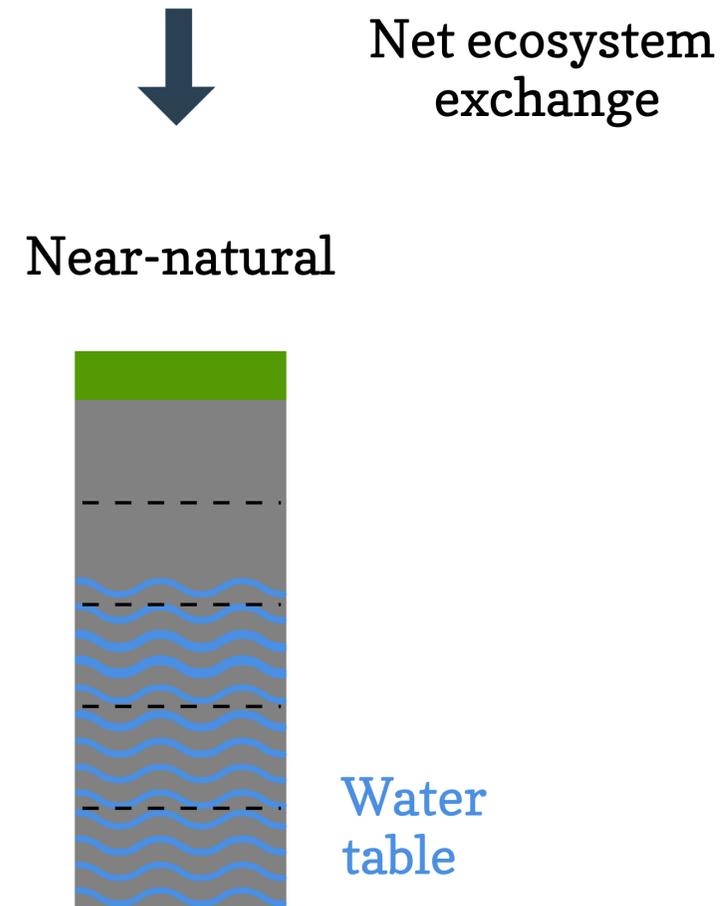
- Bacteria were structured by soil properties, assembly of fungi reflected inoculum source
- Introduction of grassland inoculum into cropland soil resulted in higher fungal diversity
- Creation of higher fungal necromass that is more persistent when stabilised onto minerals

- 
- Environmental filtering through land management-driven promotion of favourable soil properties could be fundamental to microbe-driven SOC accrual
 - Introduction of diverse fungal taxa could also help build SOC
 - Integrating soil management and microbial interventions can promote carbon accrual.

Microbial physiology is a key control of greenhouse gas fluxes and carbon accrual in peatlands

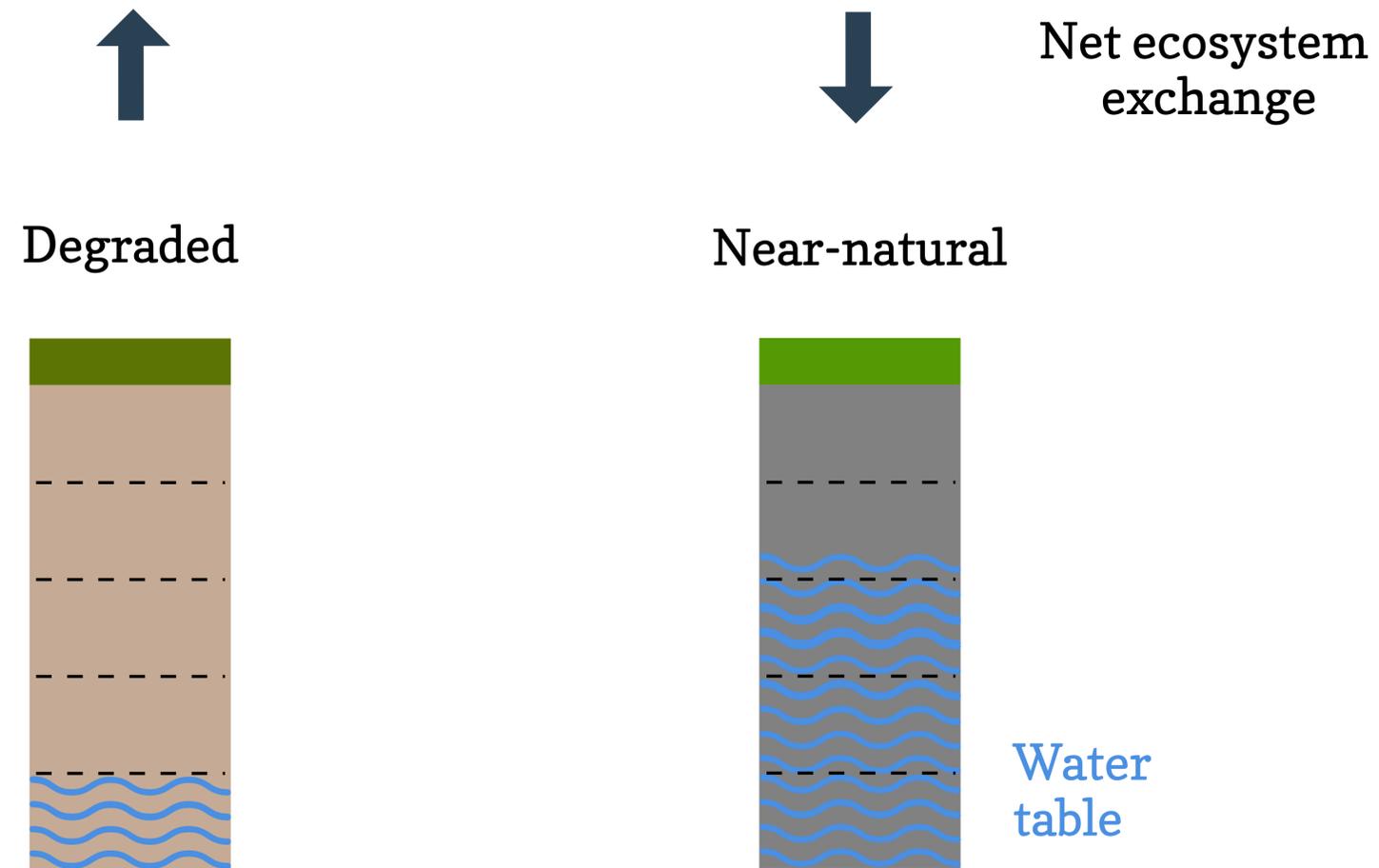


Microbial decomposition controls the carbon sink functions of peatlands

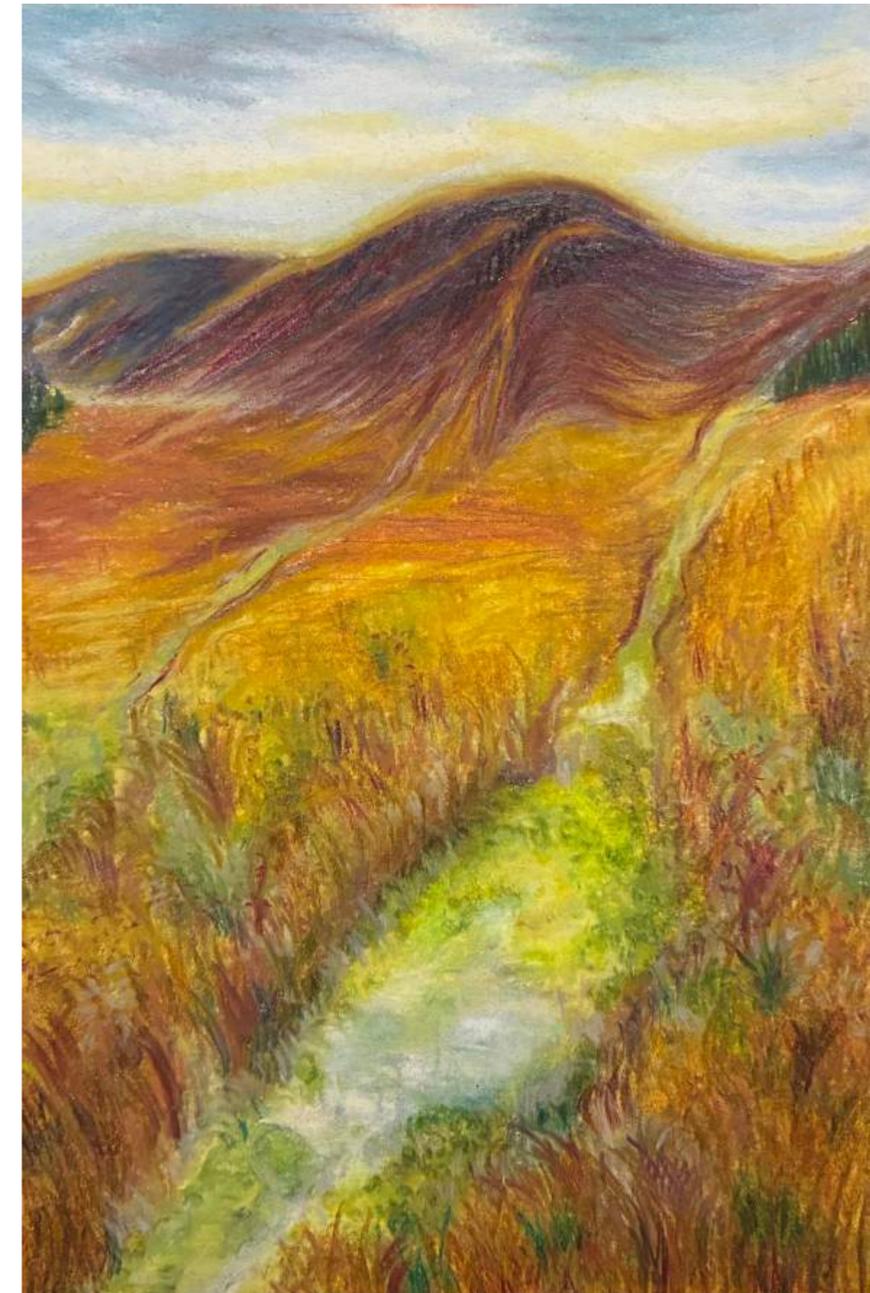
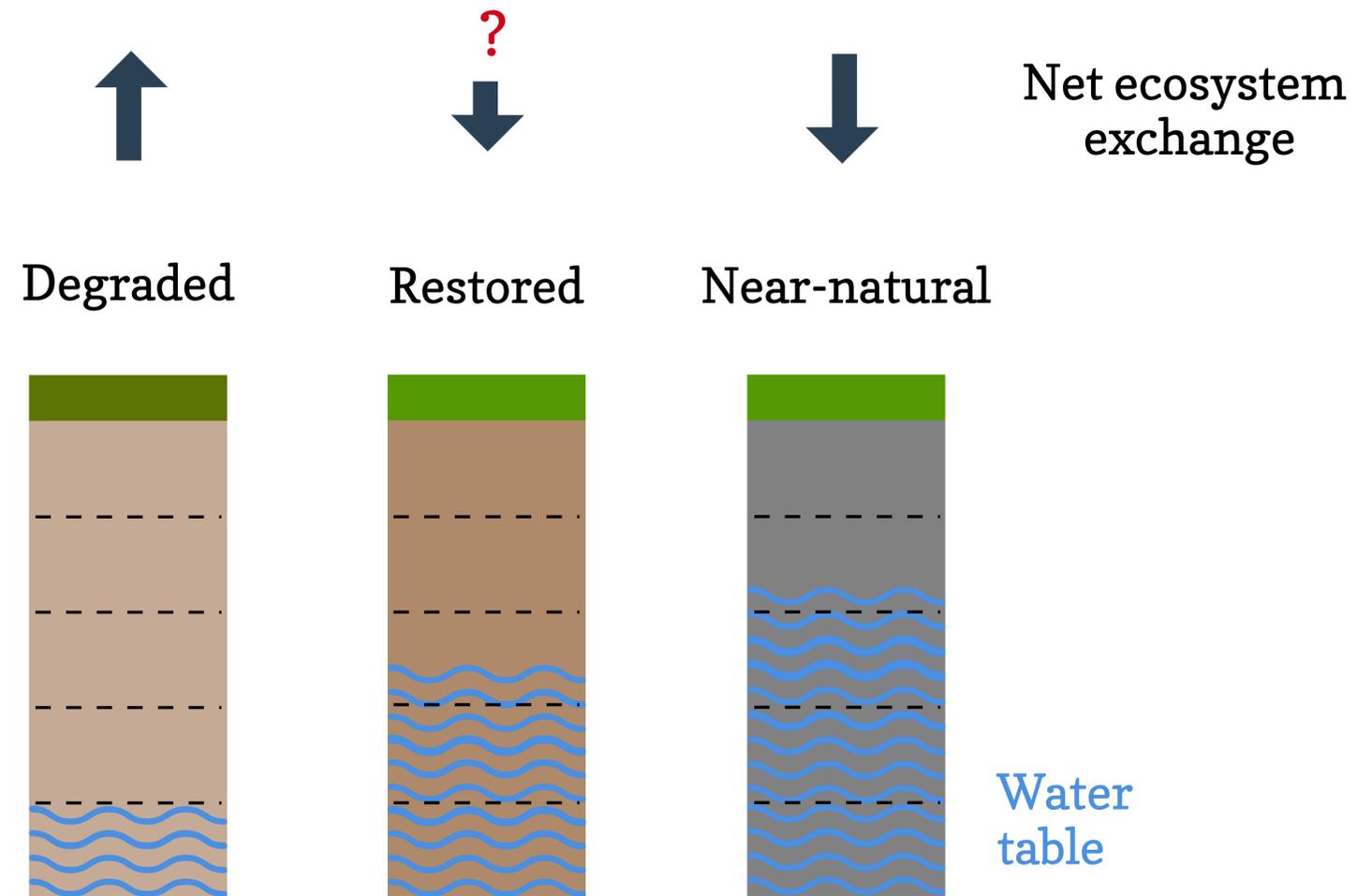


Art by
Lucy Jane MacAllister Dukes
'Mossibilities' PhD Student

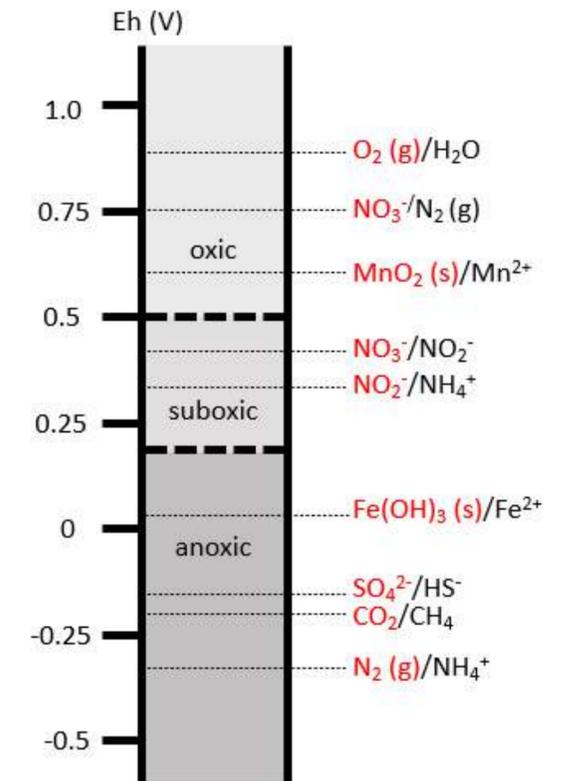
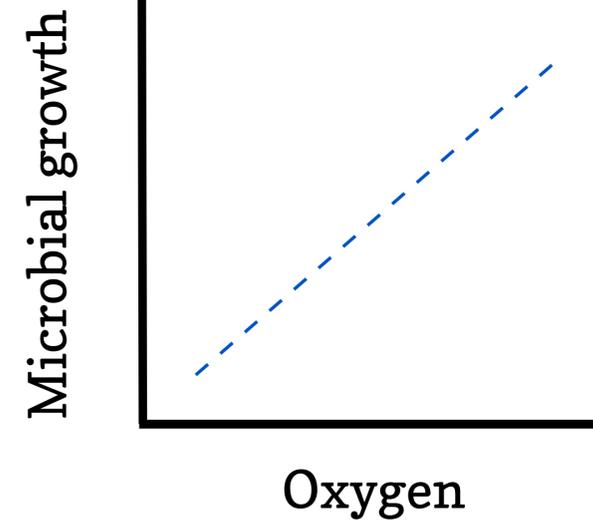
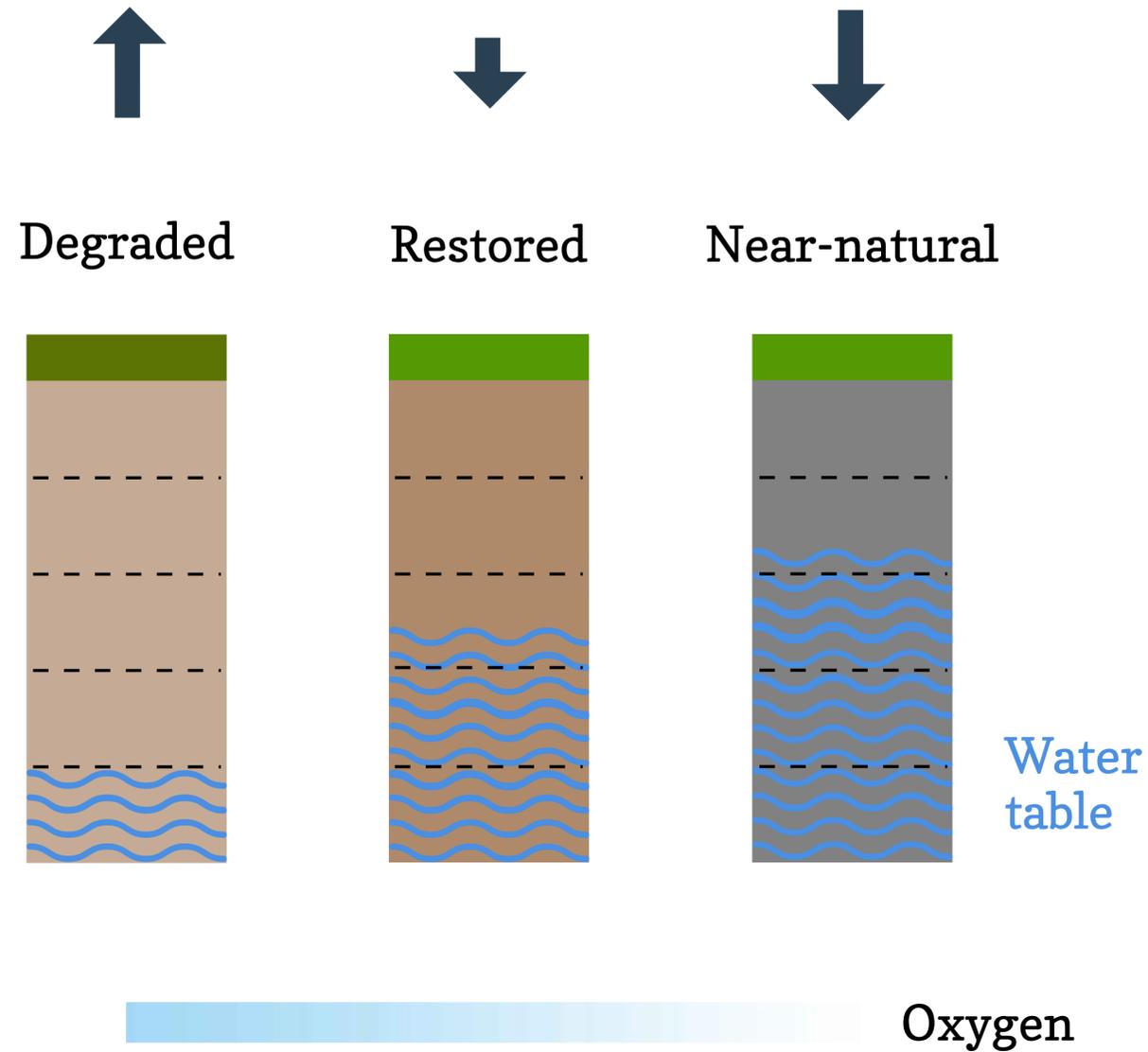
Microbial decomposition controls the carbon sink functions of peatlands



Microbial decomposition controls the carbon sink functions of peatlands

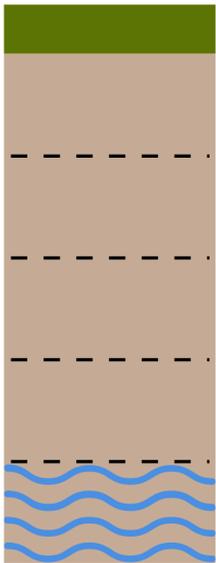


Factors affecting microbial decomposition

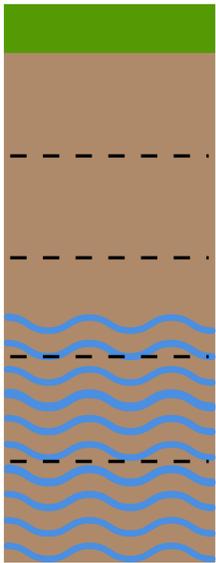


How microbial ecophysiology responds to peatland degradation and restoration to affect carbon accrual

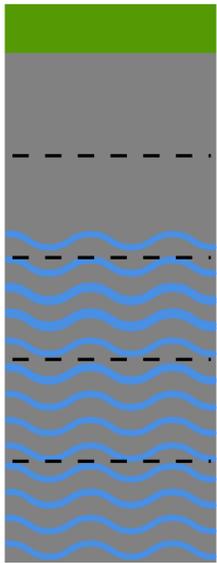
Degraded



Restored



Near-natural

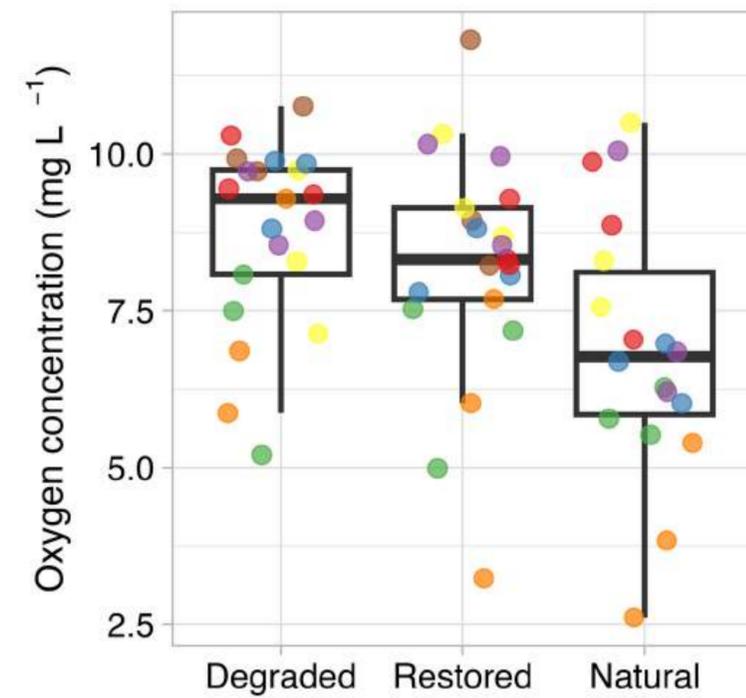
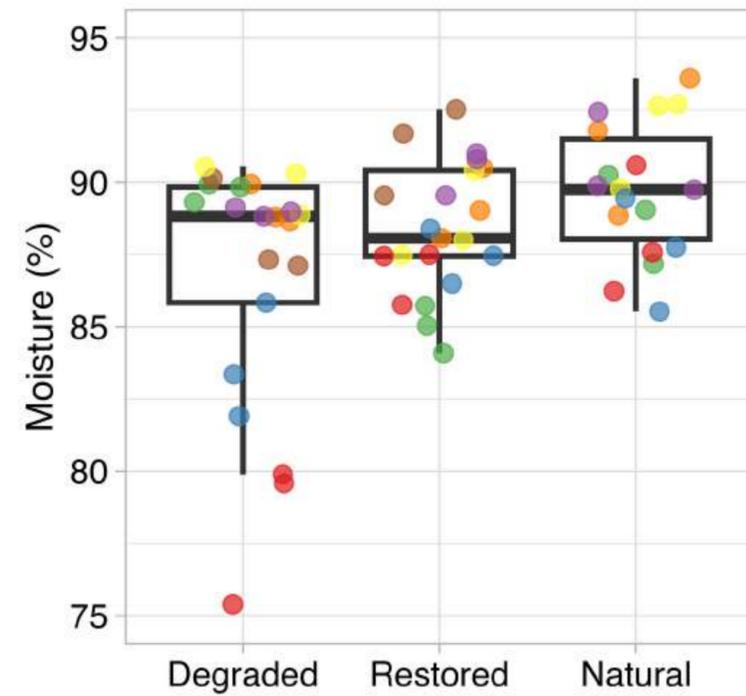


7 sites
each with
3 treatments

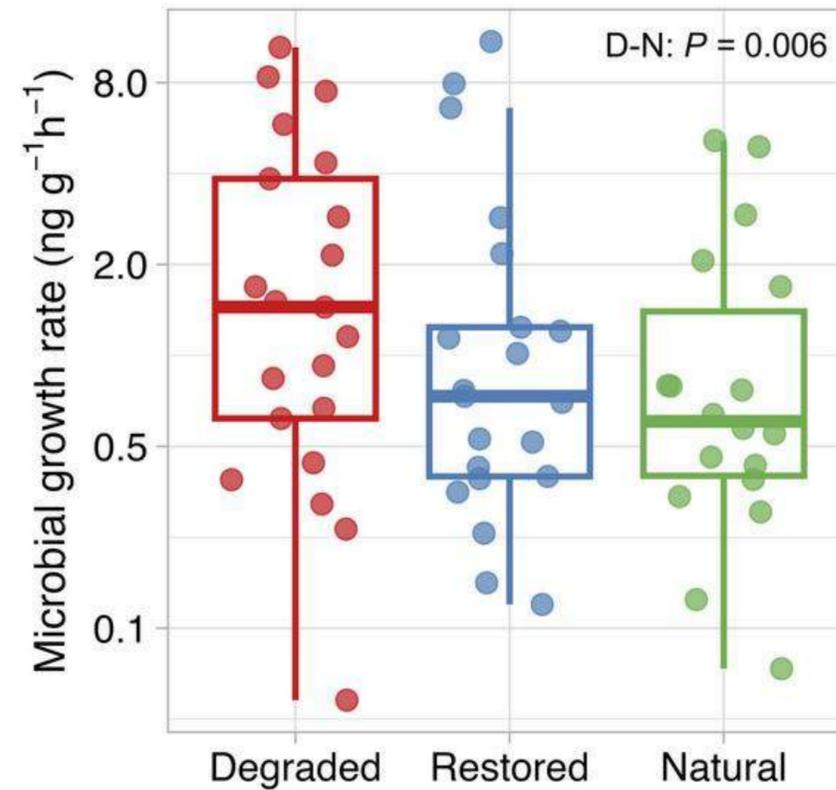
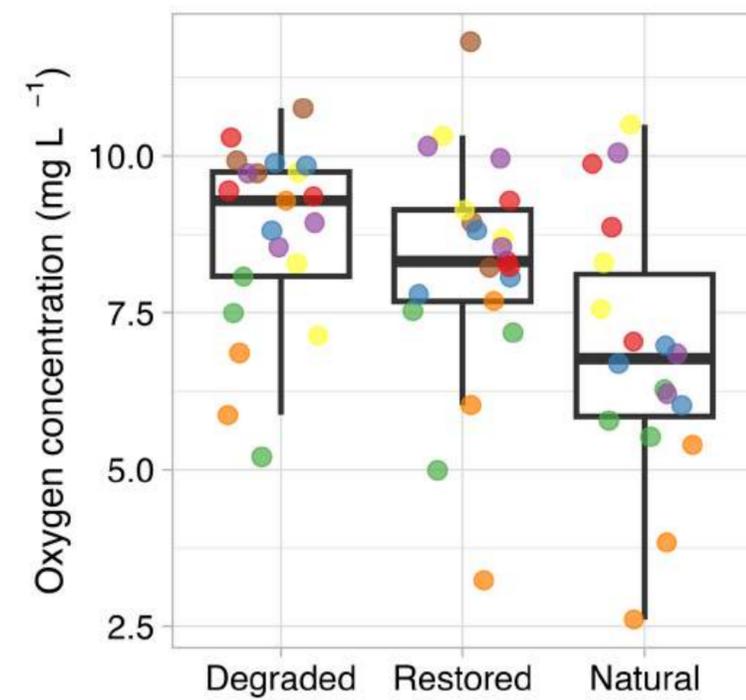
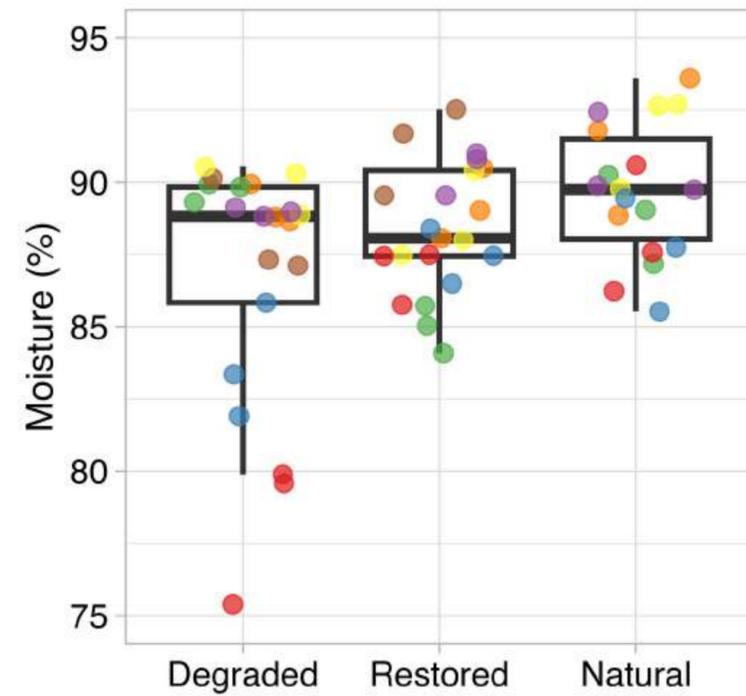


Dr William Pallier
PhD project
SUPER DTP

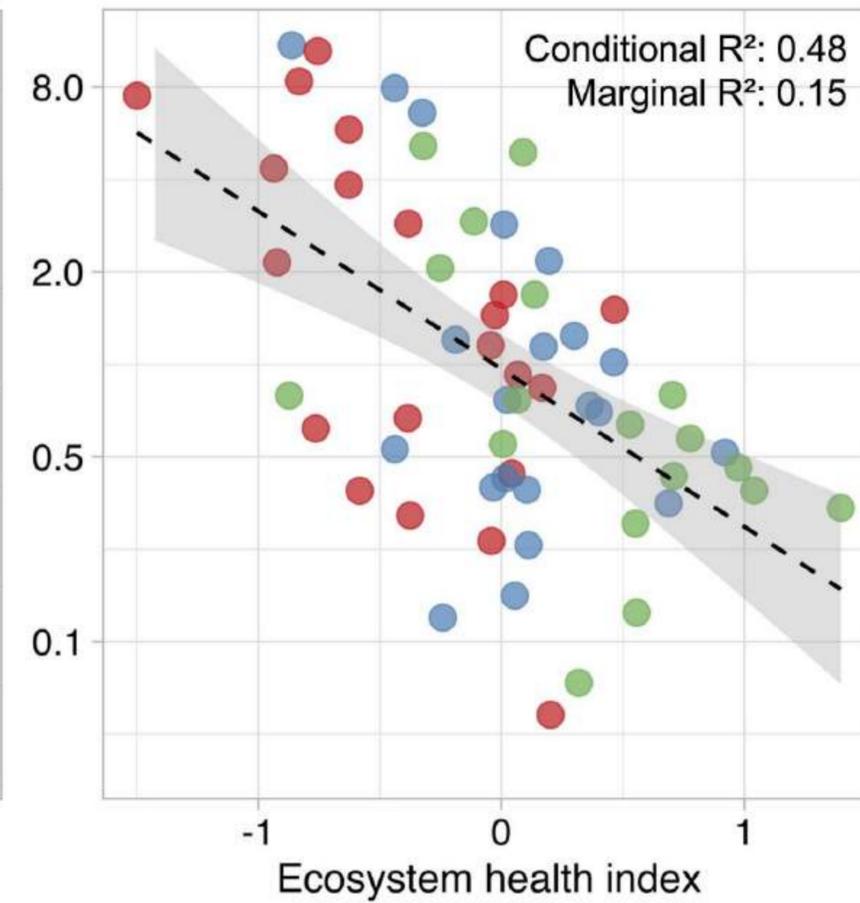
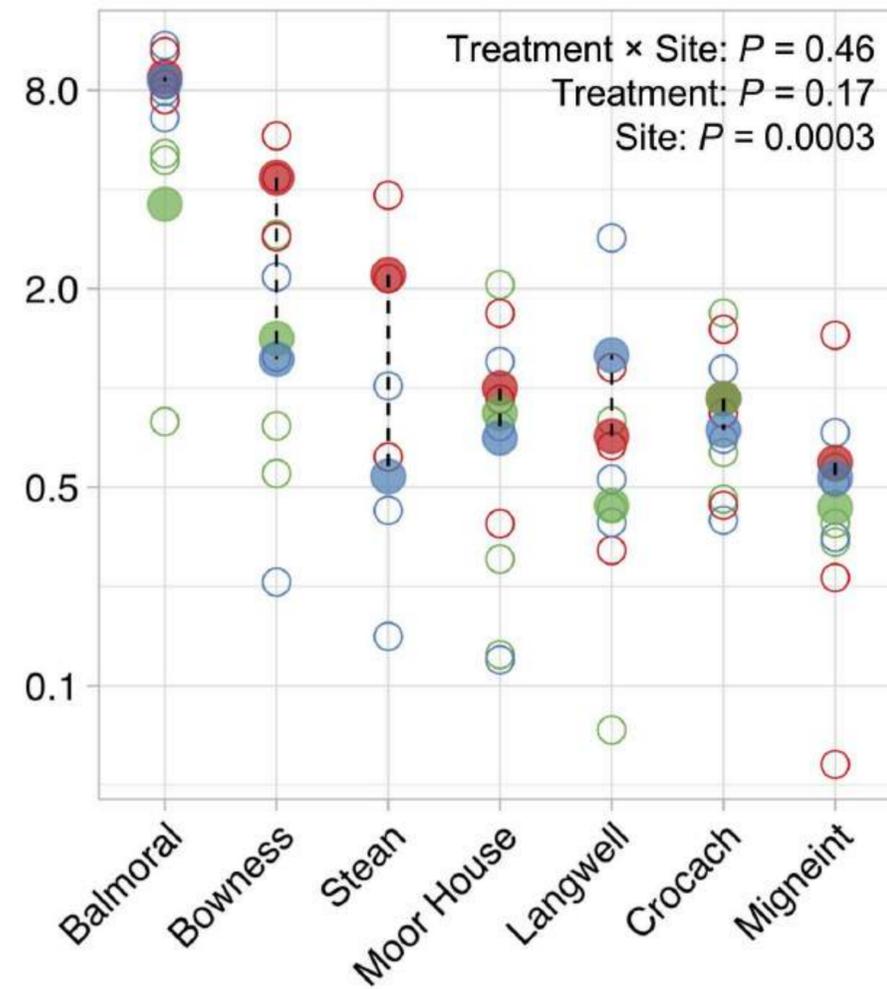
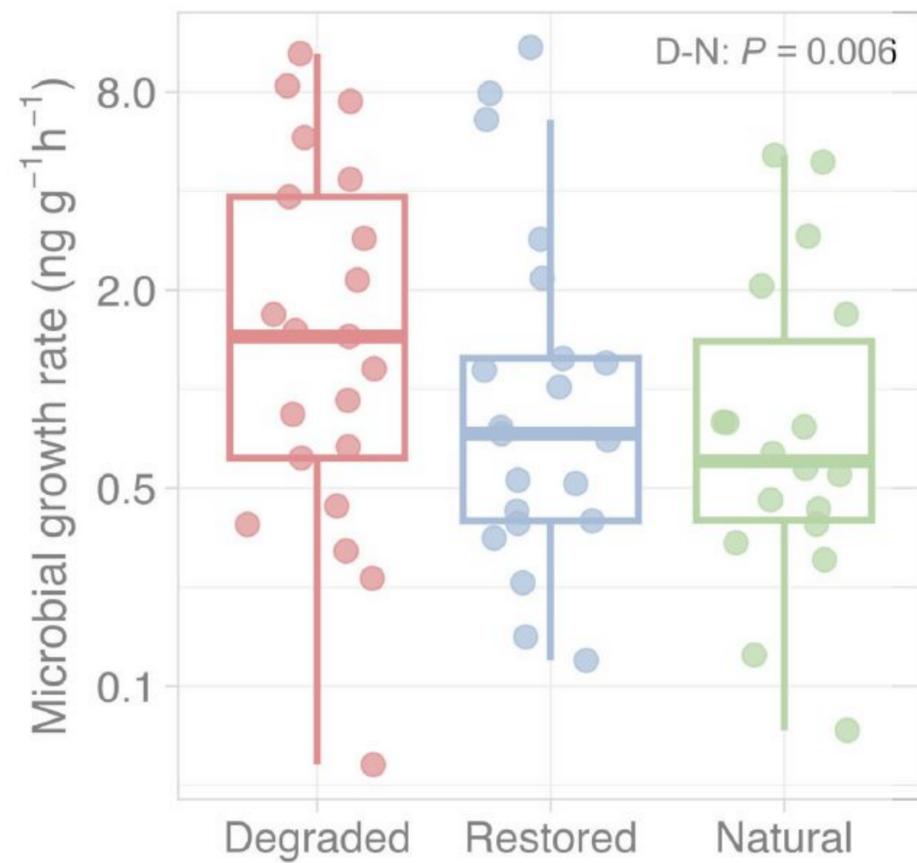
Higher oxygenation of the top layers in degraded peatlands, lower in restored and near-natural



Aerobic metabolism results in higher growth rates; signs of mitigation in restored peatlands



Microbial growth reflects levels of degradation and age of restoration

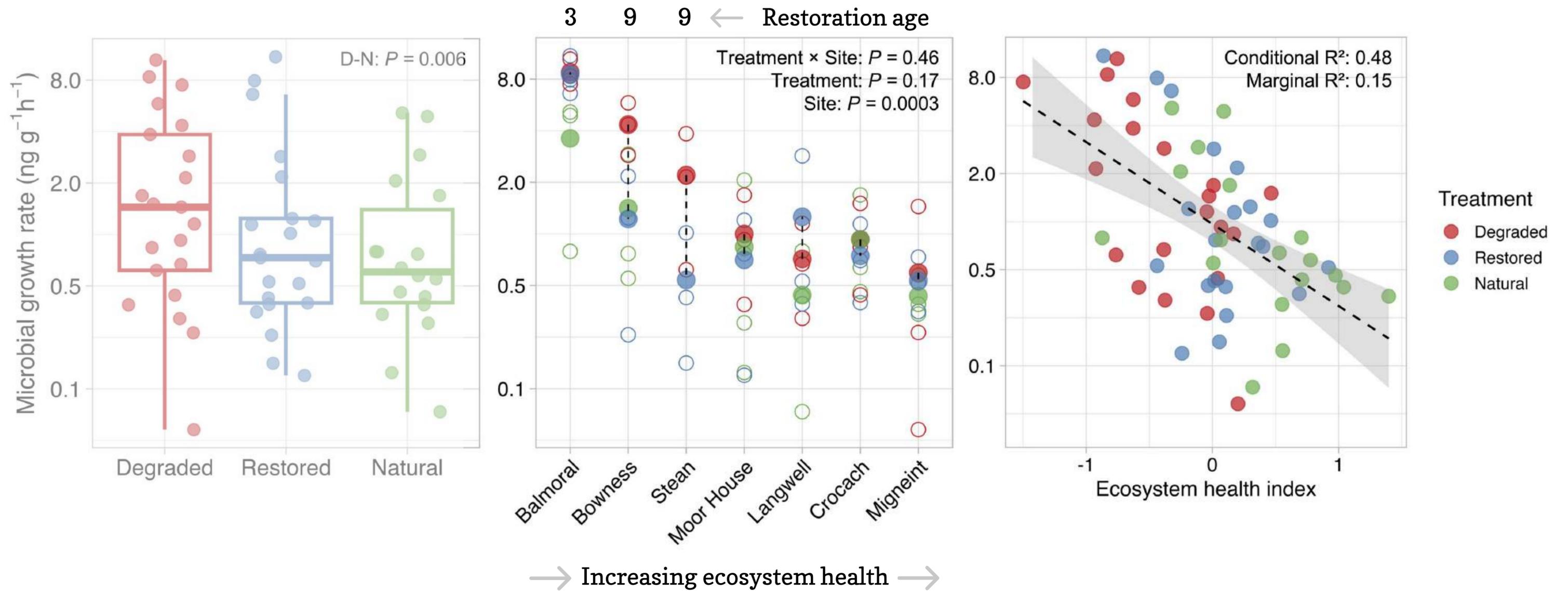


Treatment

- Degraded
- Restored
- Natural

→ Increasing ecosystem health →

Microbial growth reflects levels of degradation and age of restoration





Tree planting in a lowland site



Tree planting in an upland site



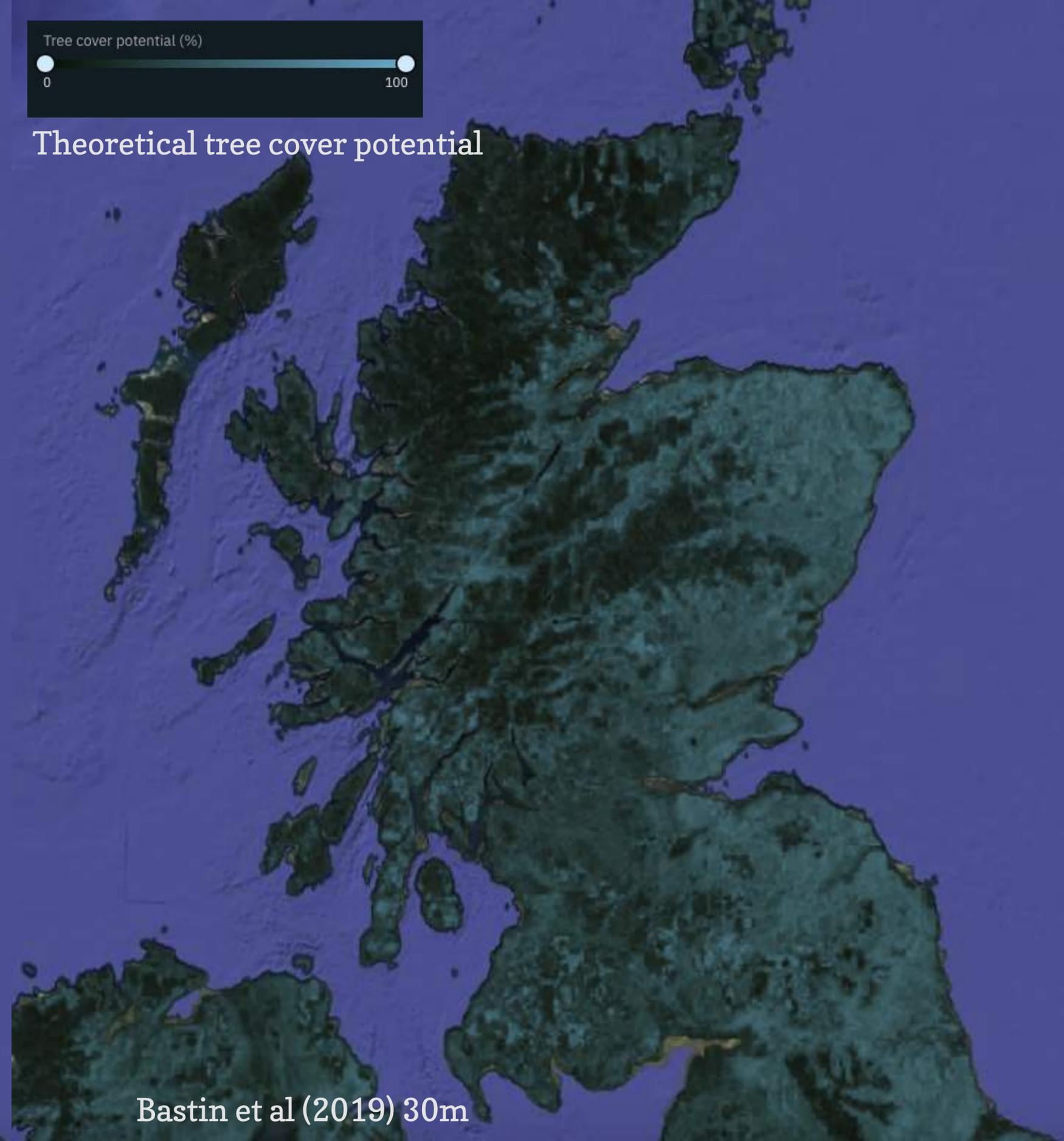
Tree cover 2010



Hansen et al (2013) 30m

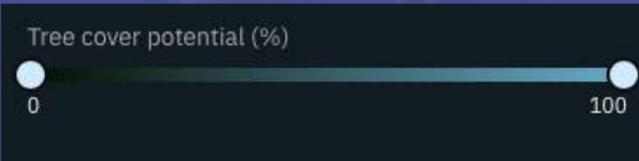


Theoretical tree cover potential

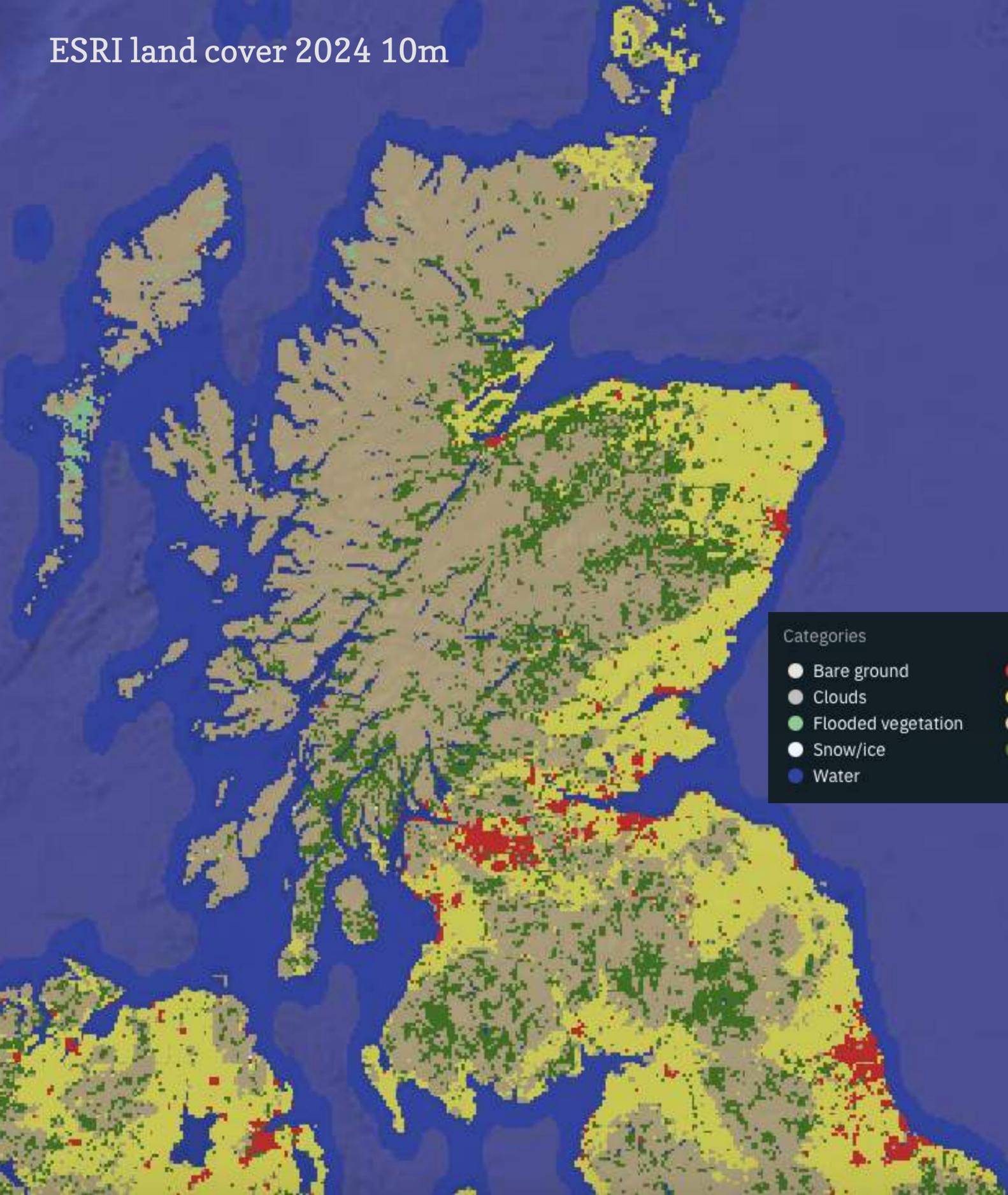


Bastin et al (2019) 30m

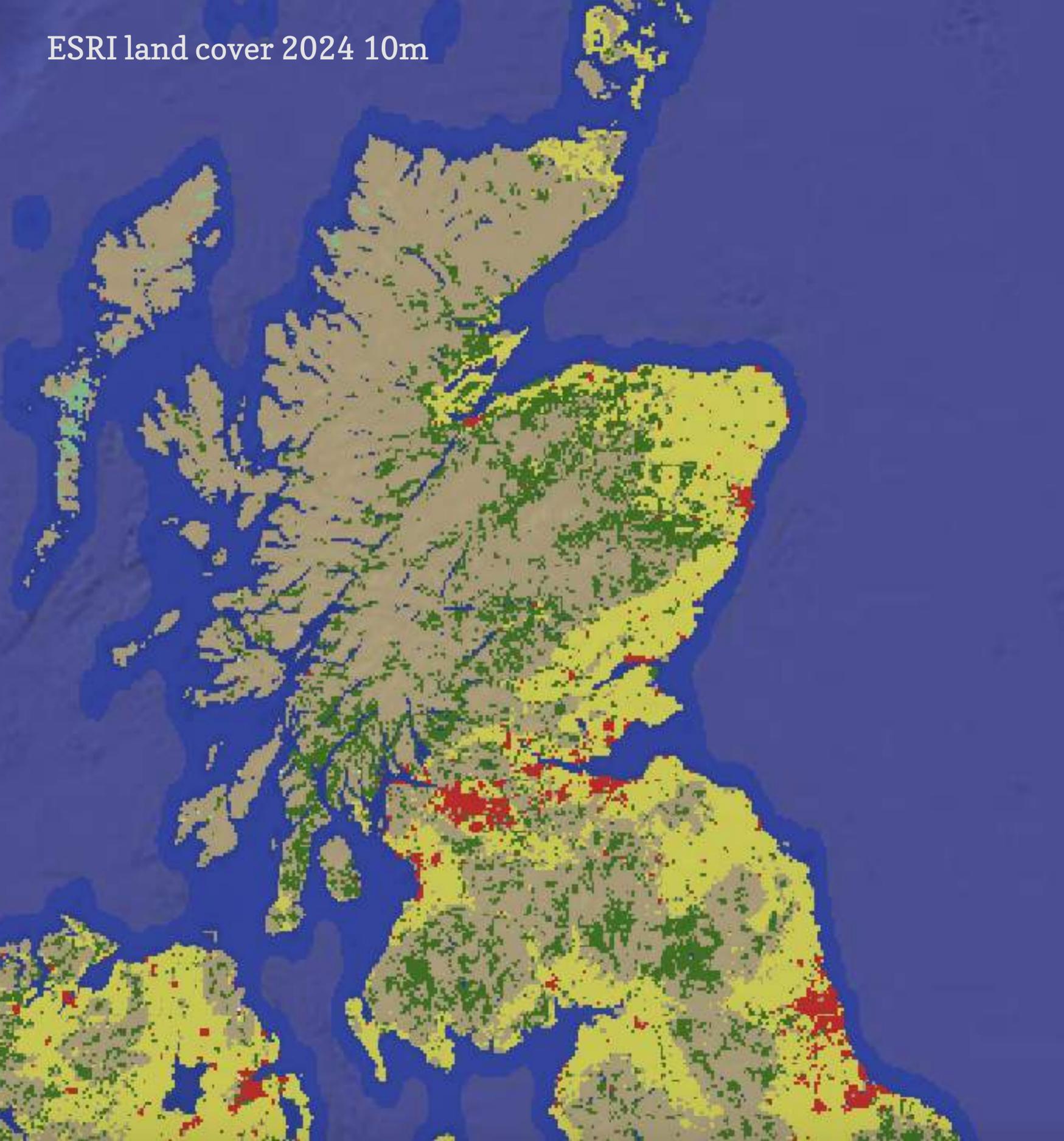
ESRI land cover 2024 10m



Theoretical tree cover potential



Bastin et al (2019) 30m



Strategies for building soil carbon stocks:

- 1) Regenerative management practices in croplands for building soil carbon through microbial necromass mineral stabilization
- 2) Peatland restoration to halt microbial decomposition and sustain carbon accumulation
- 3) Tree planting in the right places that aid in increasing belowground soil carbon