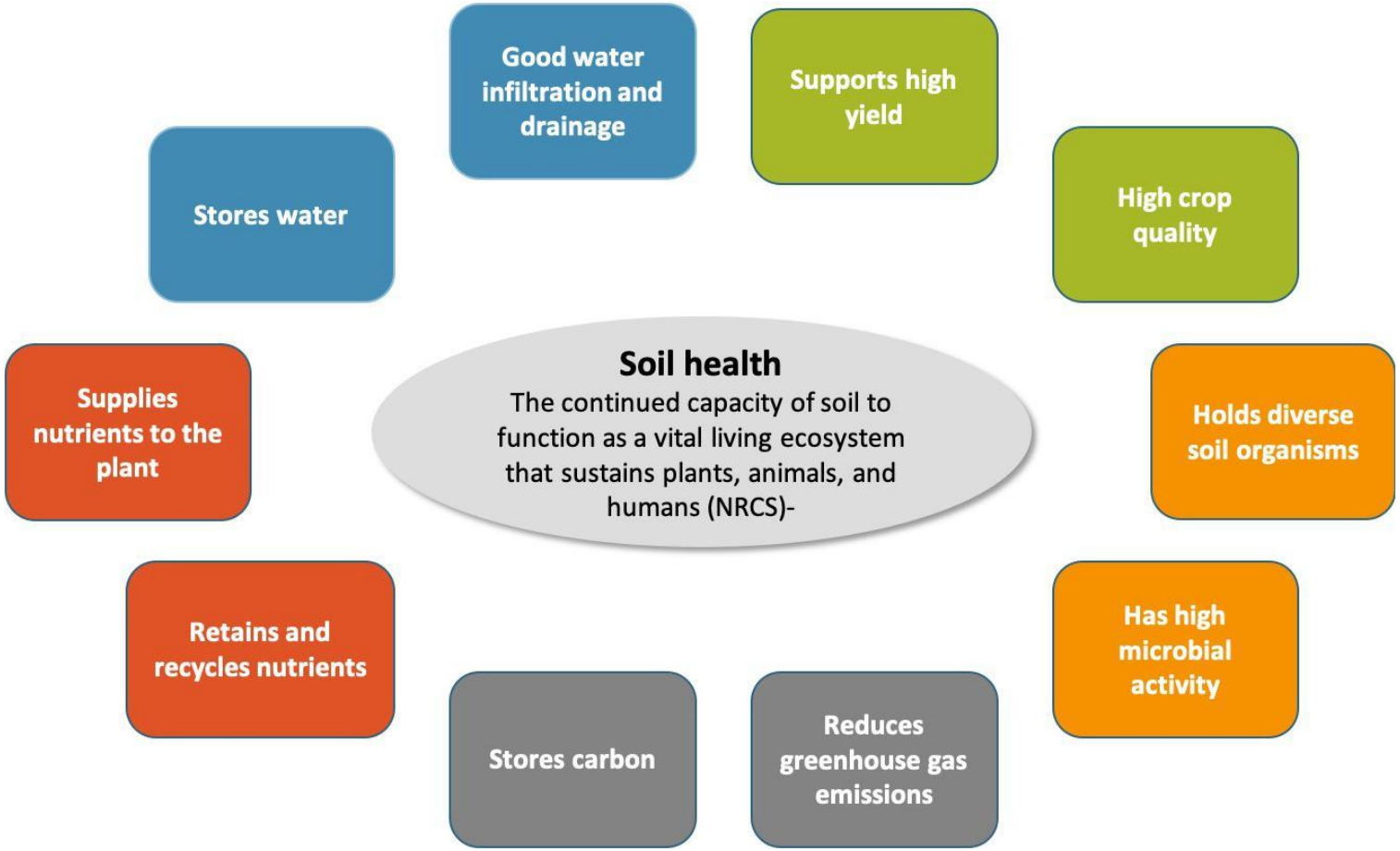
Developing a test to measure biological soil health

Dr Flora O’Brien

Soil health

"the **ability of soil to perform ecosystem services and functions**, sustaining air and water quality, in addition to supporting plant and animal health."



Lazcano et al (2020) *Frontiers in Env. Sci.* **8**

The Gap in Soil testing

Chemical

- pH
- Total N
- Total C
- SOM
- Nutrients
- CEC
- Organic C

Physical

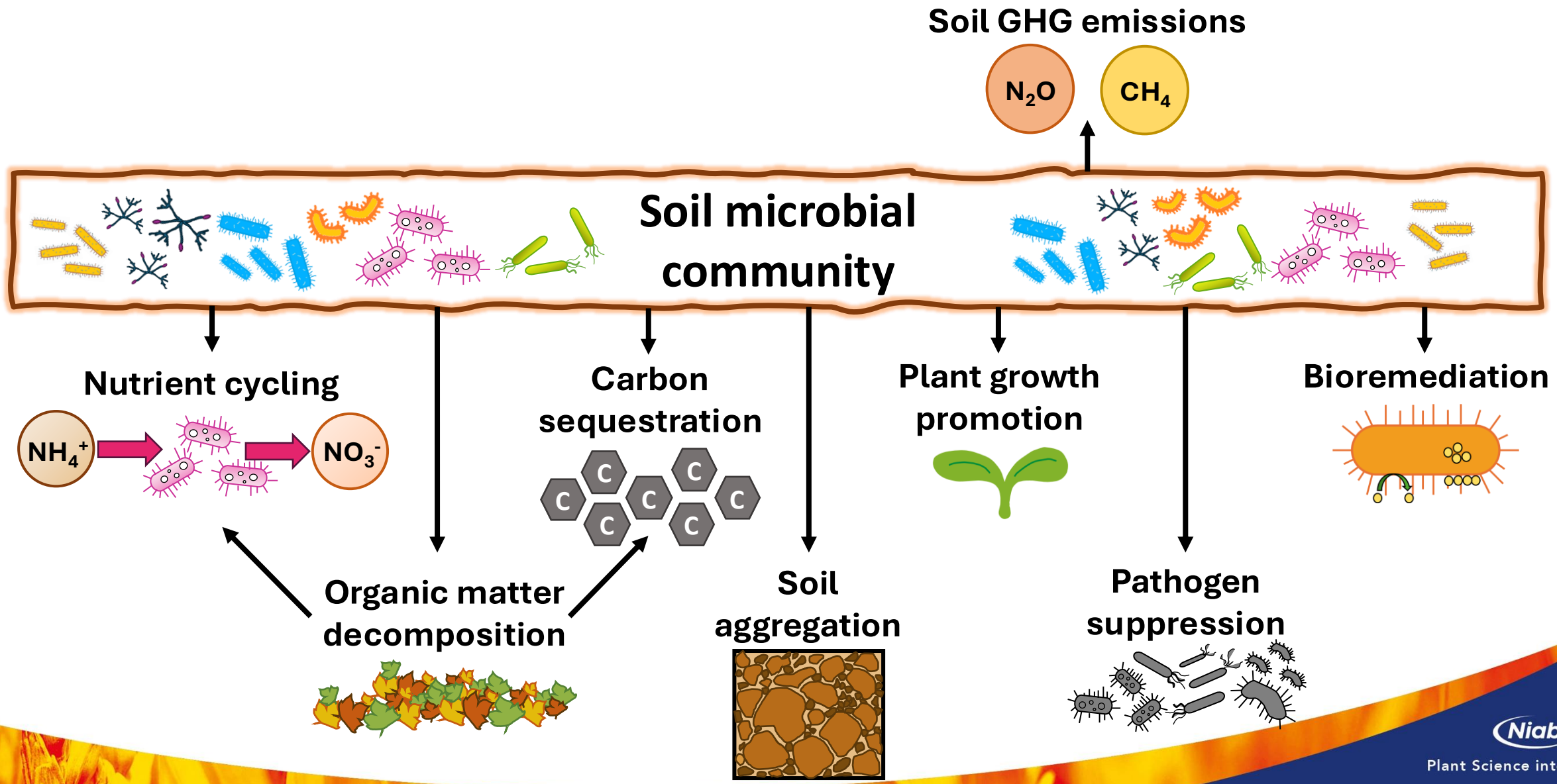
- Texture
- Structure
- Porosity
- Infiltration
- Aggregate stability
- Bulk Density
- Compaction

Biological

- Earthworm counts
- Microbial biomass
- Respiration
- Microbial substrate utilisation
- Microbial community composition

But how to measure microbial functioning?

The roles of soil microbes



The project

Aim: to develop a novel testing protocol for soil biological health by combining phospholipid fatty acid (**PLFA**) analysis and quantitative polymerase chain reaction (**qPCR**) analysis of key microbial functional genes/biological markers, to create a single measure of soil microbial community composition, or **soil biological health**.

UKRI

Environmental monitoring innovation

Innovate UK

VERDANT CARBON

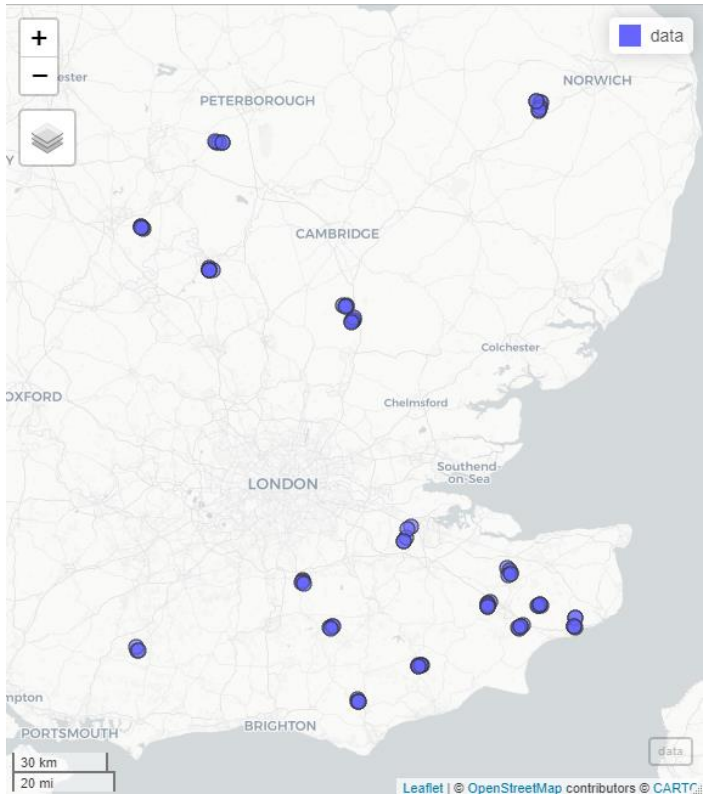
Niab

Soil sampling → **Biological profiling** + **Soil physicochemical measurements** + **Crop biomass production experiment** → **Data analysis and modelling**

Soil samples collected from sites with varying soil characteristics and management histories (236 samples in total).

Metadata gathered:

- Location (W3W)
- Previous crop
- Current Crop
- Soil type
- % moisture



VERDANT CARBON LTD	Ref: VER-SAM-FOR-005 Effective Date: 02-Dec-2024
Title: Sample Record Form	Rev: 1.0 Page: 1 of 2

Client Details

Company/Organisation			
Contact Name			
Contact Phone		E-mail	

Sample Details

Sampling SOP	VER-SAM-SOP-003
Sampling Address	
Field name	

Sample Code (ISO-date)–[initials]–[number].			
V-C Unique ID (assigned by the project team)			
Sample Location (GPS or What3Words)			
Sampling details			
Present crop		Previous crop	
Observations			

Sample Code (ISO-date)–[initials]–[number].			
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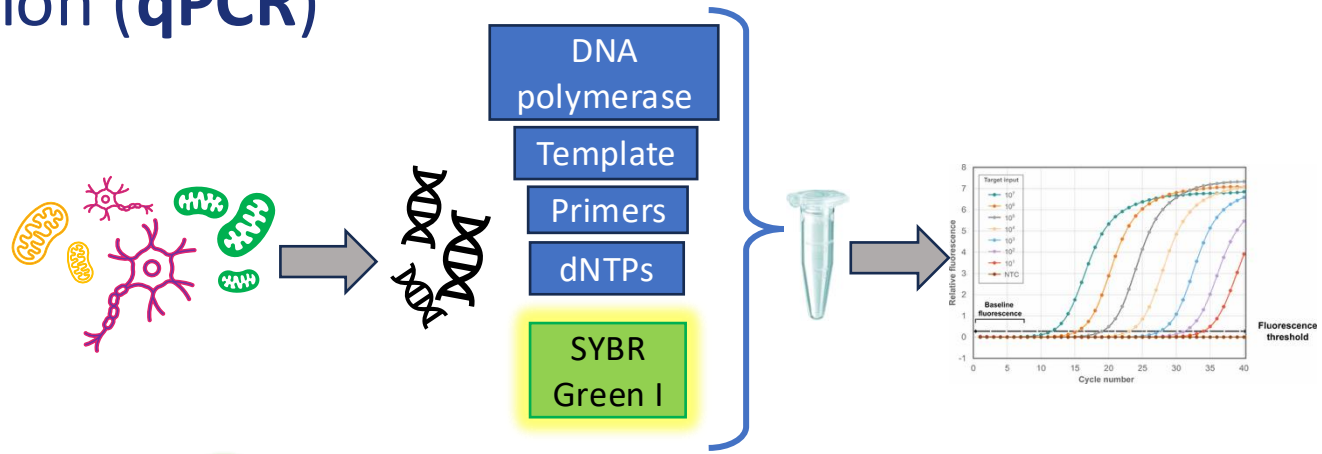
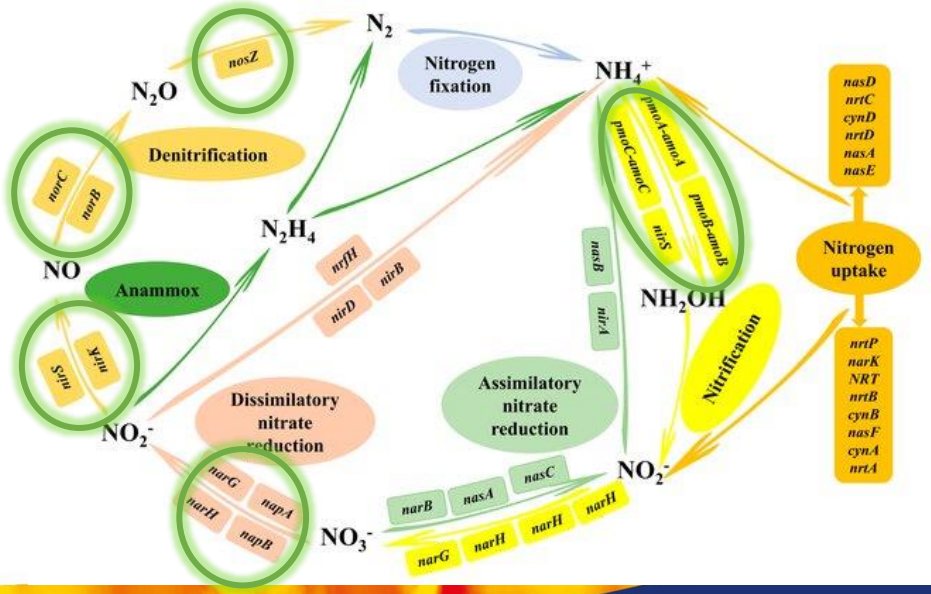
Soil sampling → **Biological profiling** + Soil physicochemical measurements + Crop biomass production experiment → Data analysis and modelling

Quantitative polymerase chain reaction (**qPCR**)

- qPCR uses fluorescent signals to monitor DNA amplification in real time.
- Detects more specific microbial groups than PLFA analysis.
- However, soil DNA extracts contain material from both living and dead microbial cells.
- Target key microbial functional genes involved in nutrient cycling, e.g. nitrification, N fixation, cellulase degradation, P mineralisation.





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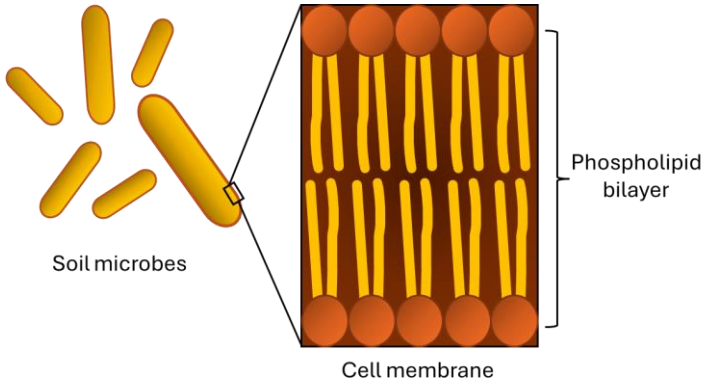
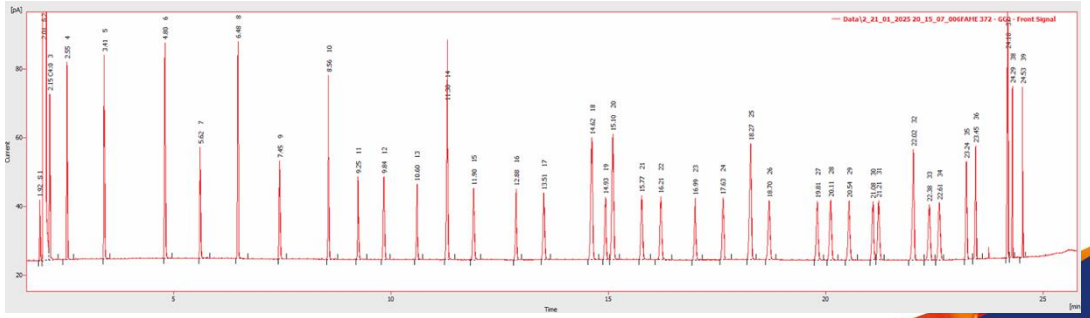
Plant Science into Practice

Soil sampling → **Biological profiling** + Soil physicochemical measurements + Crop biomass production experiment → Data analysis and modelling

Phospholipid fatty acid (**PLFA**) analysis

- PLFAs are present in all microbial cell membranes.
- Different microbial groups have distinct PLFA profiles.
- PLFAs degrade rapidly after cell death, so analysis only measures living (active) microbes.
- PLFAs are sensitive to management practices as well as soil chemical properties.
- Profiles can be used to estimate soil microbial biomass, gram-negative and gram-positive bacteria, fungi: bacteria ratios and AMF.
- Lacks specificity for more detailed microbial diversity.





Chromatogram (Verdant Carbon)

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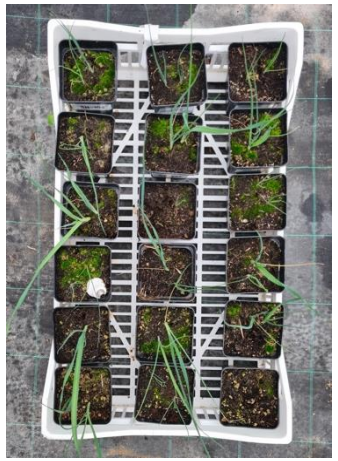
Soil sampling → Biological profiling + Soil physicochemical measurements + Crop biomass production experiment → Data analysis and modelling

- qPCR analysis
- PLFA analysis

- Total C/N (DUMAS method)
- Soil pH
- Soil texture
- Soil nutrient content

Soil sampling → Biological profiling + Soil physicochemical measurements + **Crop biomass production experiment** → Data analysis and modelling

- **Four crops:** Lettuce ('Salad Bowl'), Cabbage ('Derby Day'), Leek ('Lyon – Prizetaker) and perennial ryegrass.
- Each grown in 2 pots of each soil sample per experiment (n=3).
- Chlorophyll measurements taken from cabbage and lettuce pre-harvest.
- At harvest (7-9 weeks after sowing), above- and below-ground biomass recorded.
- Soil samples collected for nutrient analysis.



Soil sampling → Biological profiling + Soil physicochemical measurements + Crop biomass production experiment → Data analysis and modelling

- Soil parameters with the strongest correlations with crop biomass were:
  - Phosphorus
  - Potassium
  - pH
  - **nosZ gene** (qPCR)
  - **nirS gene** (qPCR)
  - **Bacteria:Fungi ratio** (PLFA)

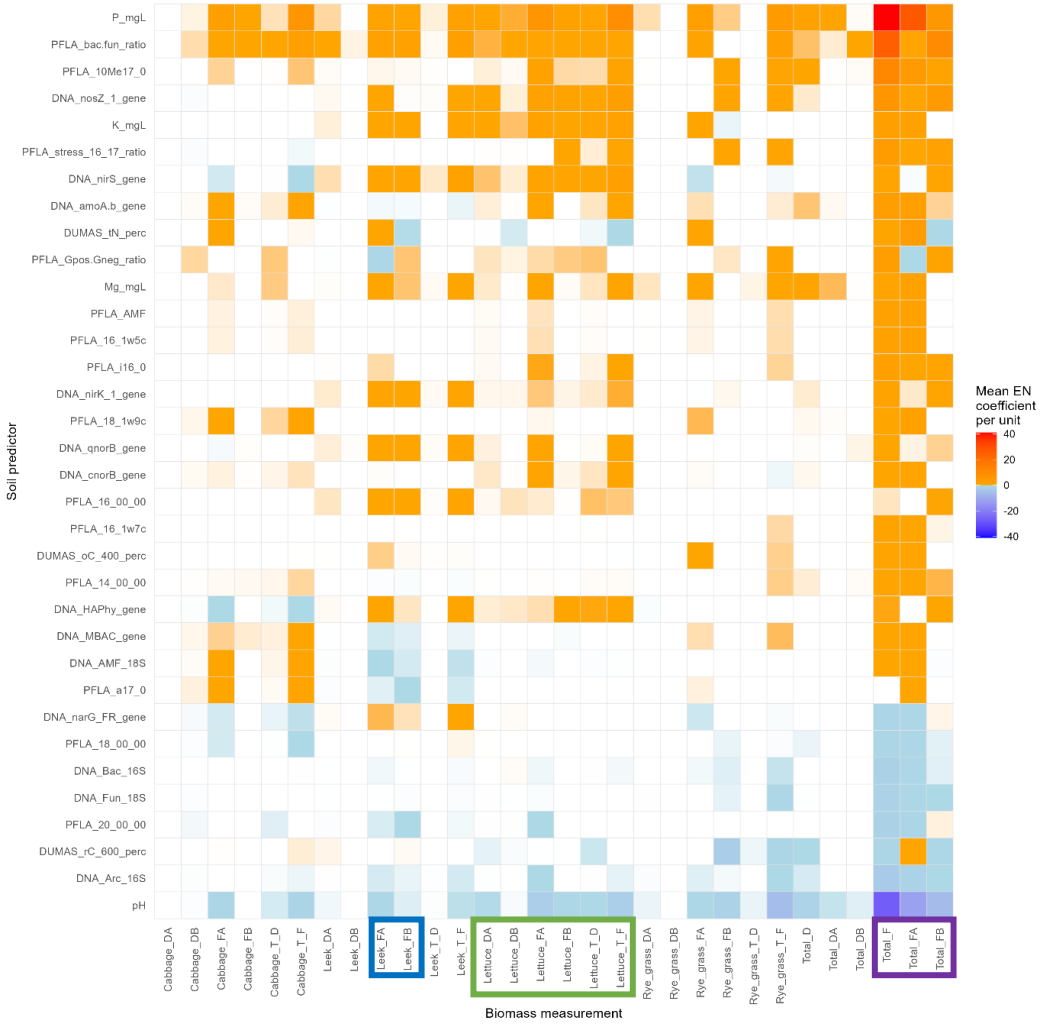
Nitrous Oxide reductase gene - converts N2O to N2

Nitrite reductase gene - converts nitrite to nitric oxide

- Lettuce (all biomass measurements), Leek (fresh biomass only) and combined total (all crops) exhibited the best correlations with soil parameters.

Future work

- Longer and larger-scale study to strengthen the model and develop a scoring system for soil biological health.



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