



Centre for  
Agriculture  
and the  
Bioeconomy

# Understanding the interactions of nitrogen and carbon in soil

## Increasing plant-available forms and avoiding losses

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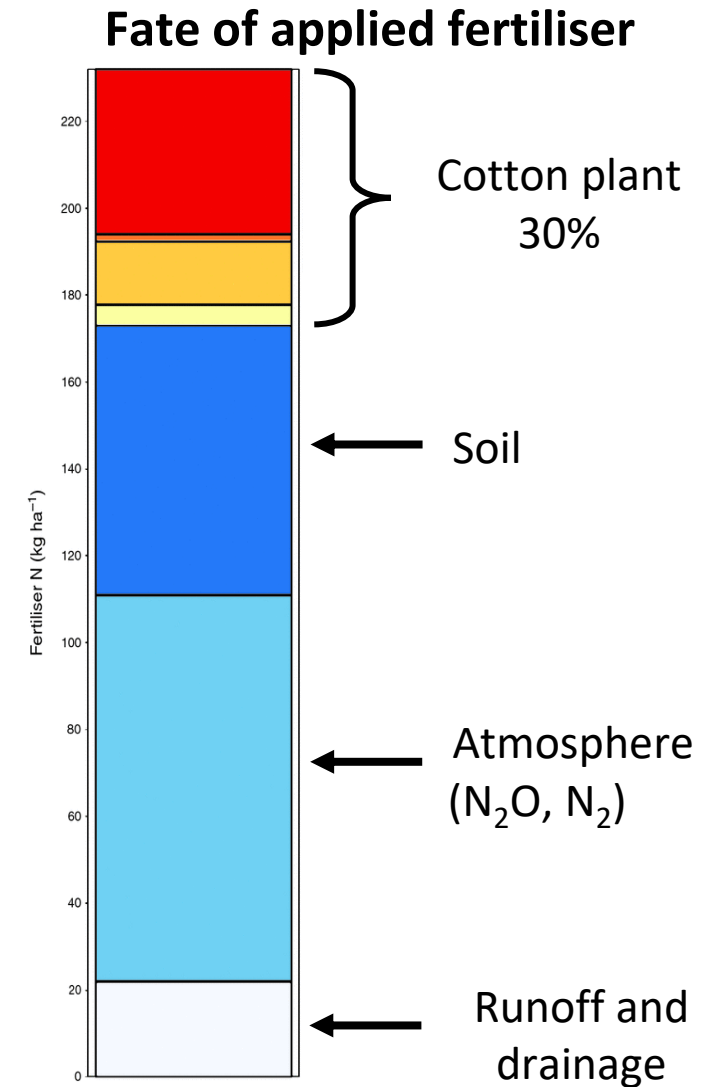
Agricultural Soils Forum | 18<sup>th</sup> June 2026

# Outline

- Crop sources of nitrogen
- How nitrogen become available from soil organic matter
- Role of soil carbon in nitrogen mineralisation and availability
- Integrating soil health with nitrogen management
- Risks of soil nitrogen losses to denitrification

# Crop capture of fertiliser nitrogen

- On average, <50% of fertiliser N taken up by crop
- 20-48% retained in soil
- 6-38% lost to atmosphere and waterways

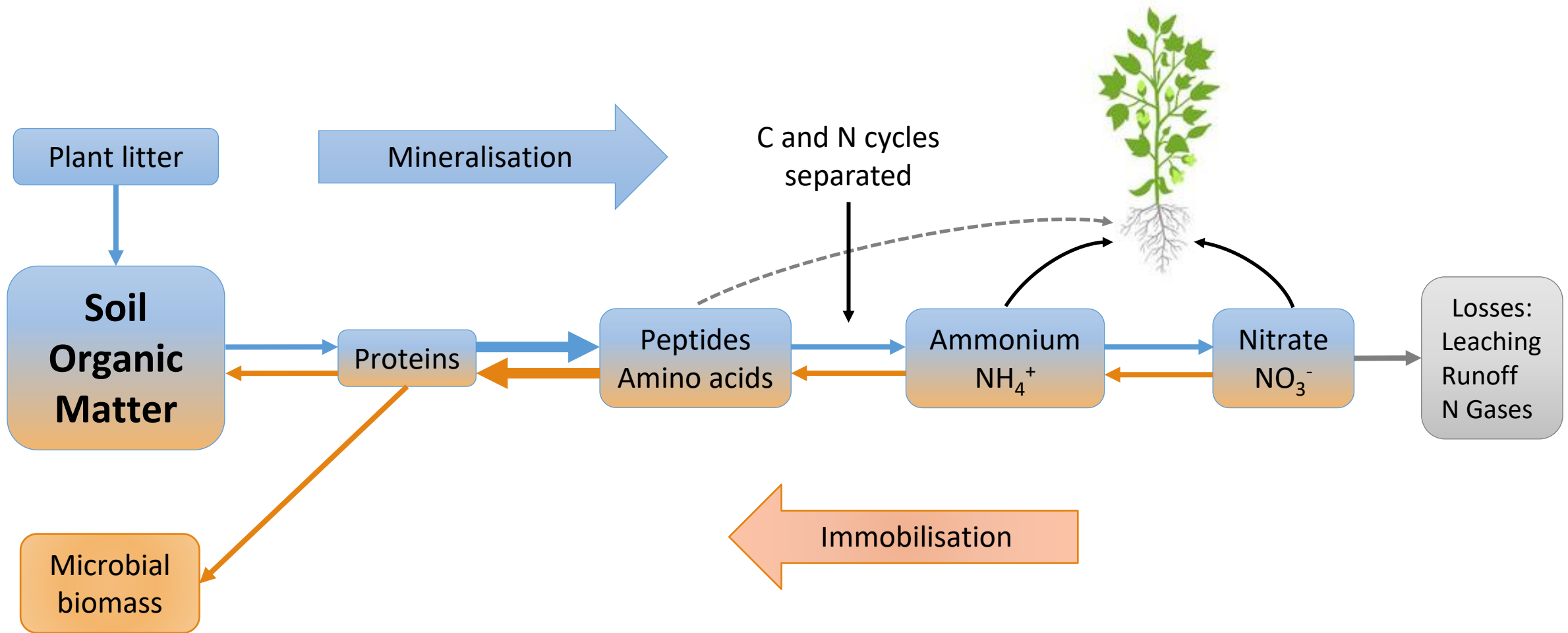


(Macdonald et al. 2018, *Soil Research*.)

# Improving nitrogen fertiliser efficiency

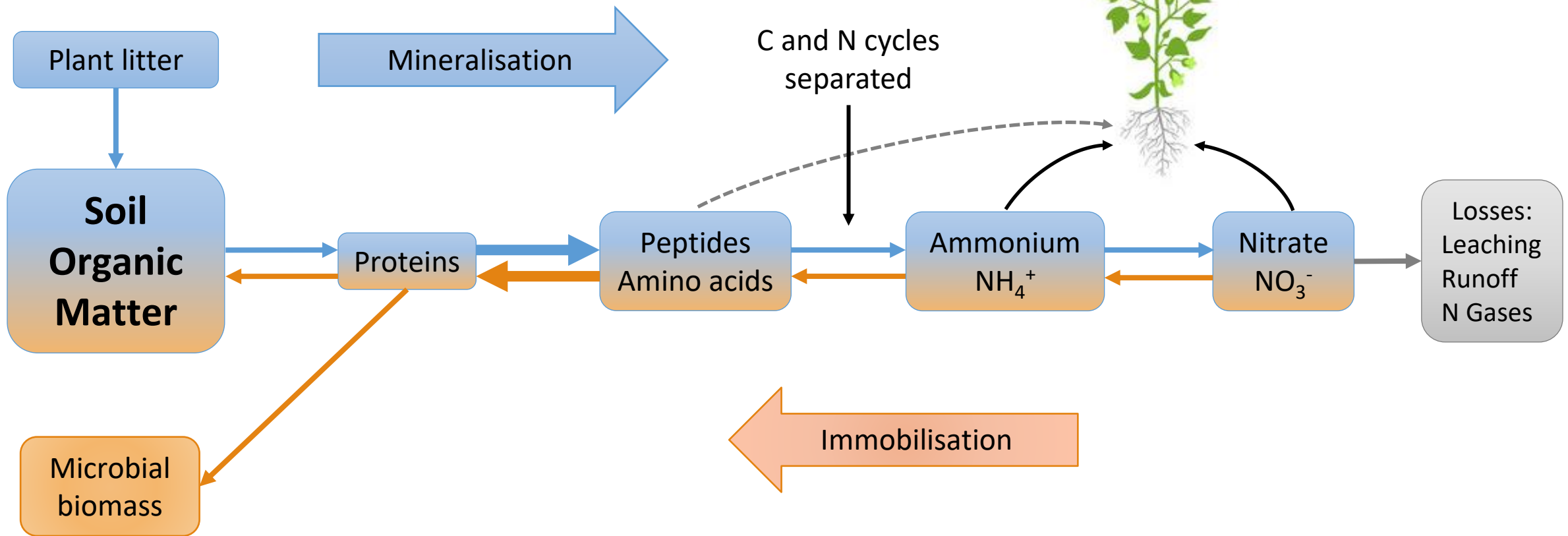
- Low fertiliser recovery:
  - Financial costs - supply constraints, instability
  - Environmental – nitrous oxide (N<sub>2</sub>O) emissions, nitrate leaching/runoff
- Strategies:
  - Reduce reliance on fertiliser
  - Capture more applied fertiliser N
  - Minimise losses

# Nitrogen cycling in soils



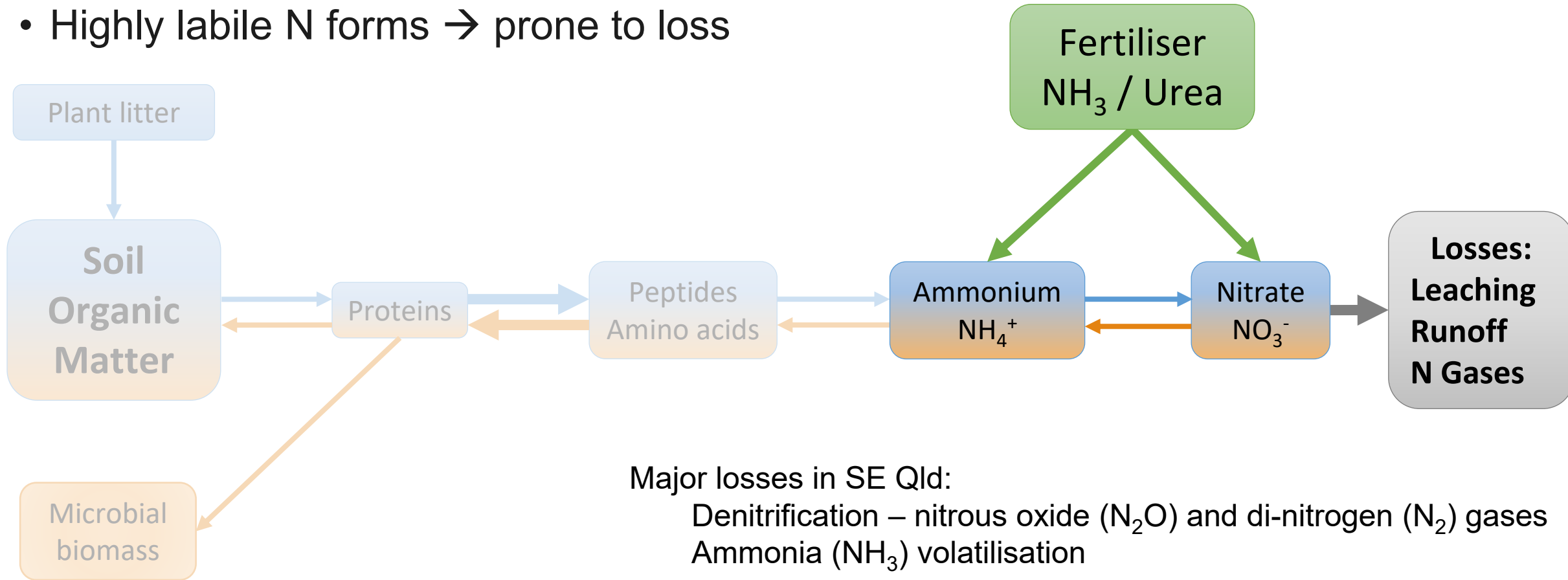
# Soil carbon and nitrogen are inherently linked

- >95% of soil nitrogen found in organic matter
  - 4-5 t N/ha in top 0-30 cm

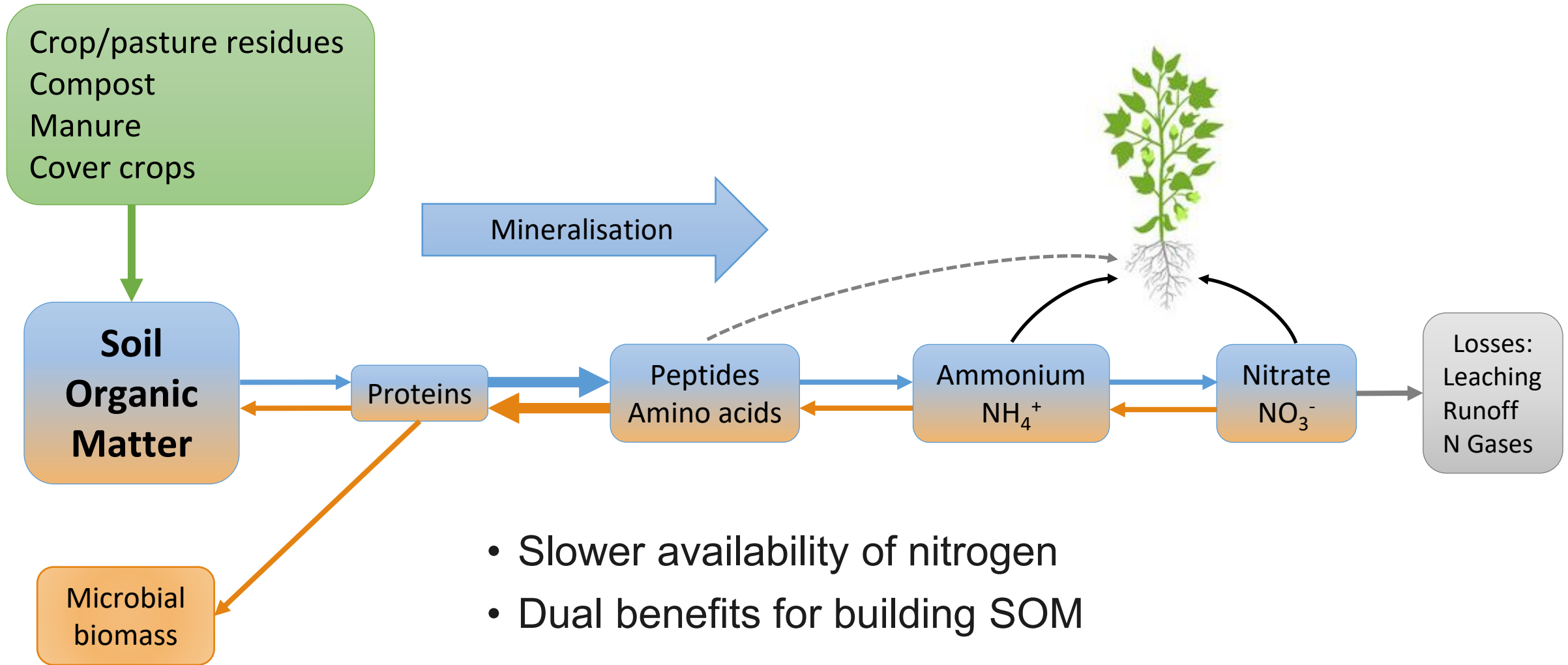


# Fertiliser bypasses most N cycling pathways

- N rapidly available – exceeds plant demand
- Highly labile N forms → prone to loss

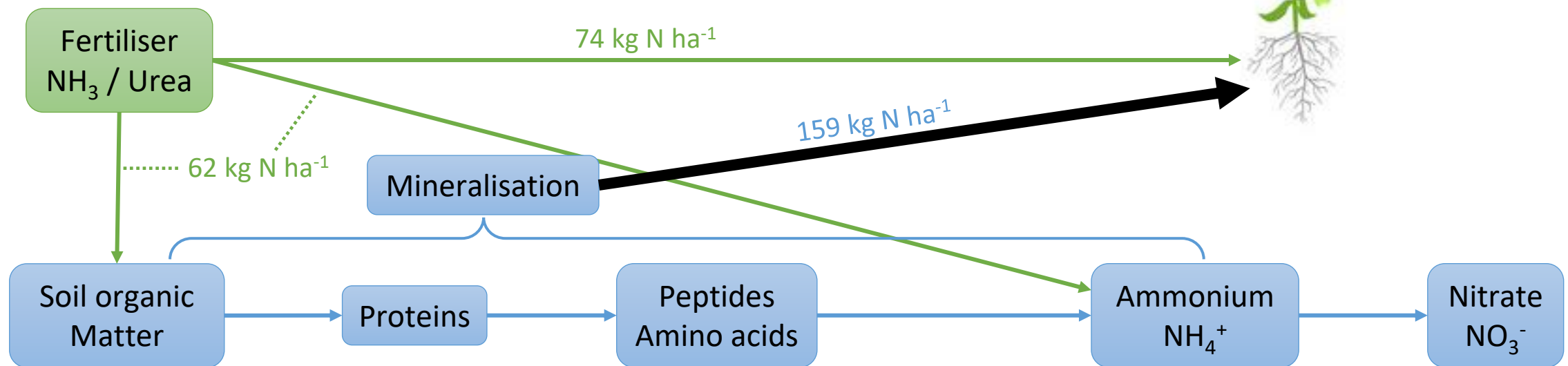


# Organic amendments supply N via mineralisation



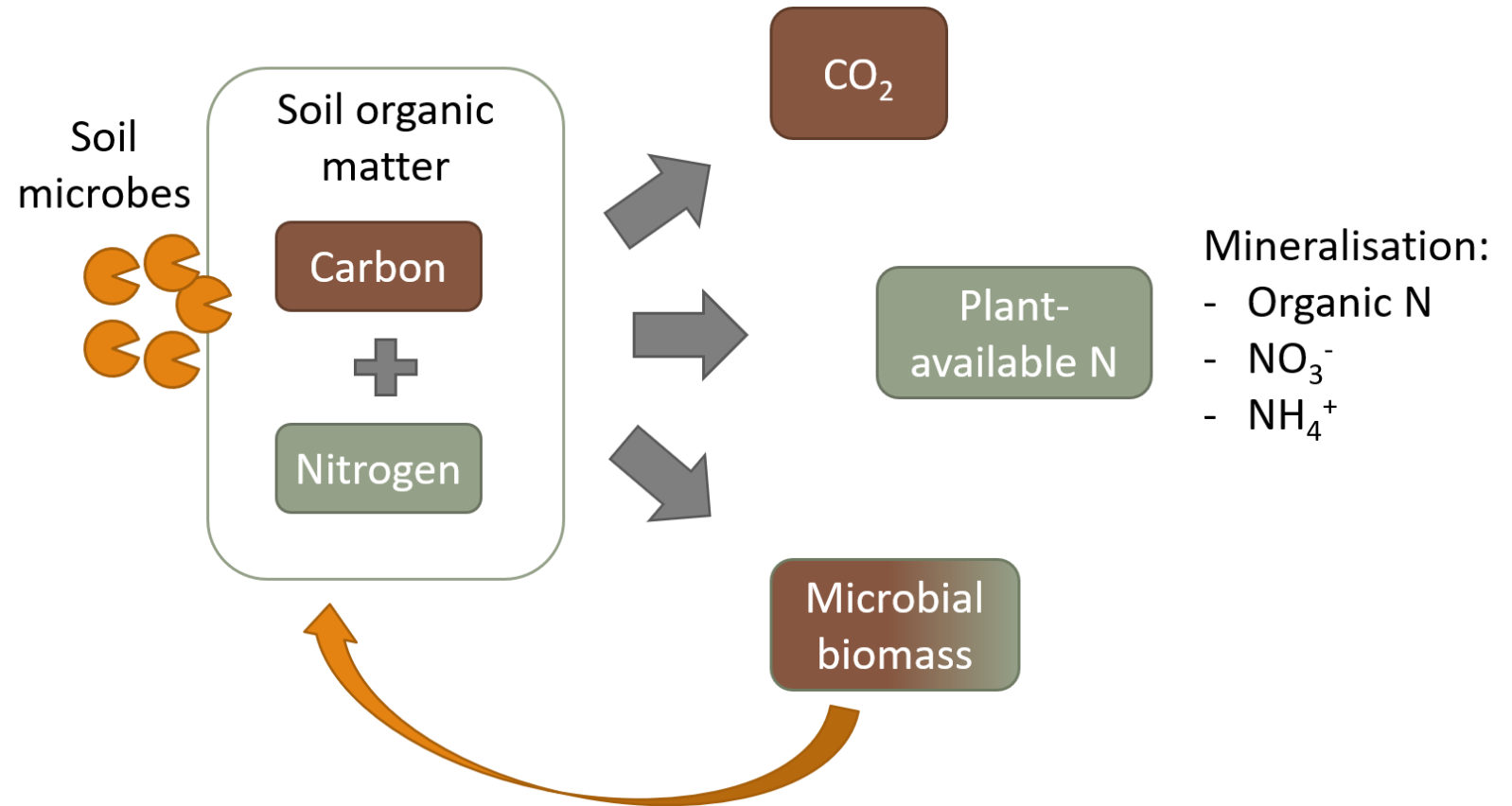
# Mineralisation is important nitrogen supply pathway

- Soil provides more than half nitrogen to crop
  - Even when sufficient fertiliser applied
  - Nitrogen mineralisation + previous year's fertiliser
- Soil-derived N across industries –
  - Grains (50-60%), cotton (70-80%), dairy (80%), sugar (60-80%)



# Nitrogen release from soil organic matter

- Microbes in soil feed on soil organic matter (decomposition)
- Mineralisation occurs when N excess to microbial needs for growth → waste product
- Immobilisation happens when high C available → microbes scavenge available N



# What controls how much N is mineralised?

- Three main factors:
  - Relative C and N availability – C/N ratio
  - Microbial growth and activity
  - Labile carbon availability

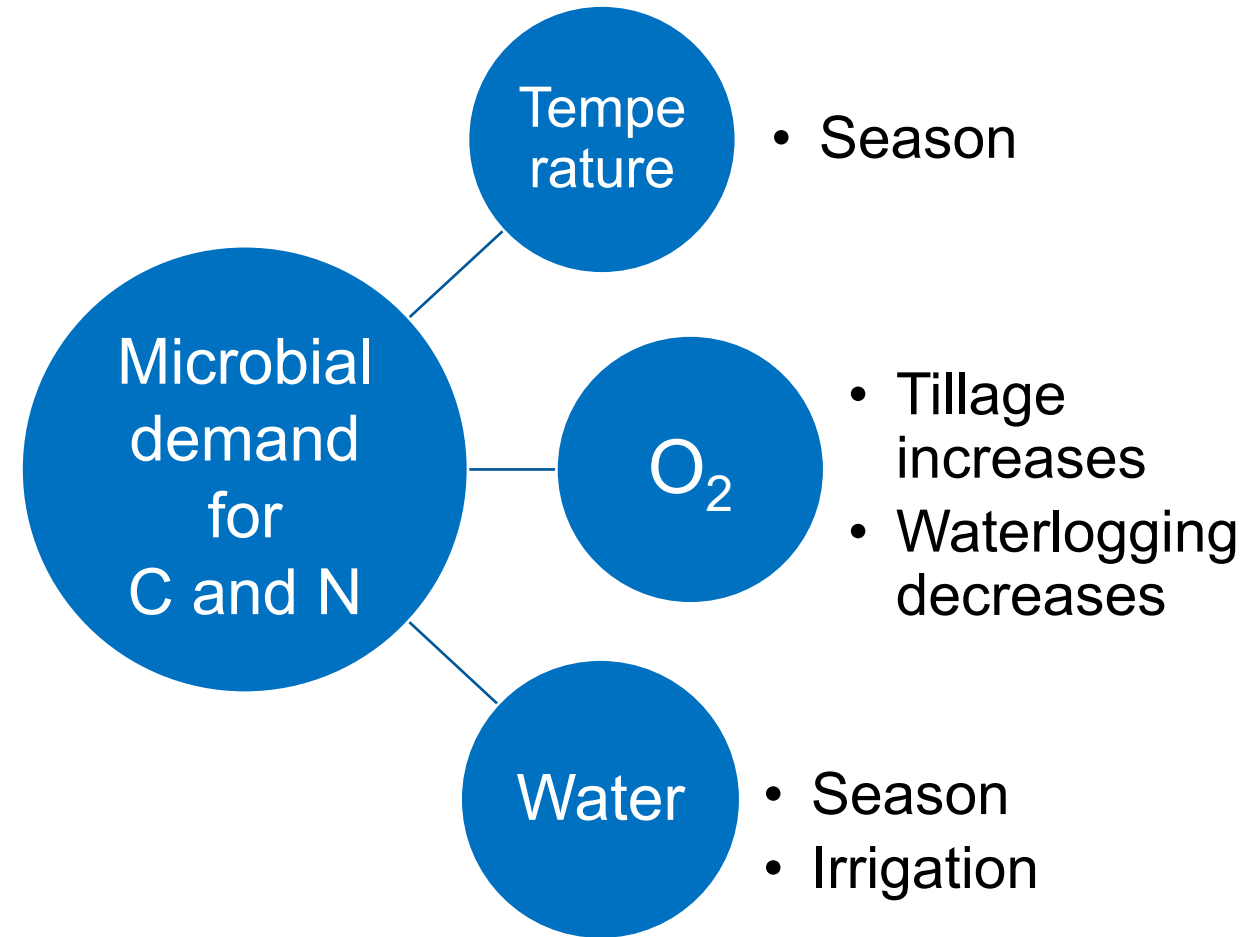
# Relative carbon to nitrogen availability

- C:N ratio can be used to predict nitrogen mineralisation or immobilisation
- Lower than 20-30 – net mineralisation likely
- Greater than ~30 – net immobilisation likely

Organic N source	Typical C/N ratio
Soil organic matter	10-14
Cereal crop residues	60-100
Legume crop residues	33-56
Immature legume residues	17-23
Compost	3-33
Manures	29-119
Biosolids	5-9

# Microbial growth and activity

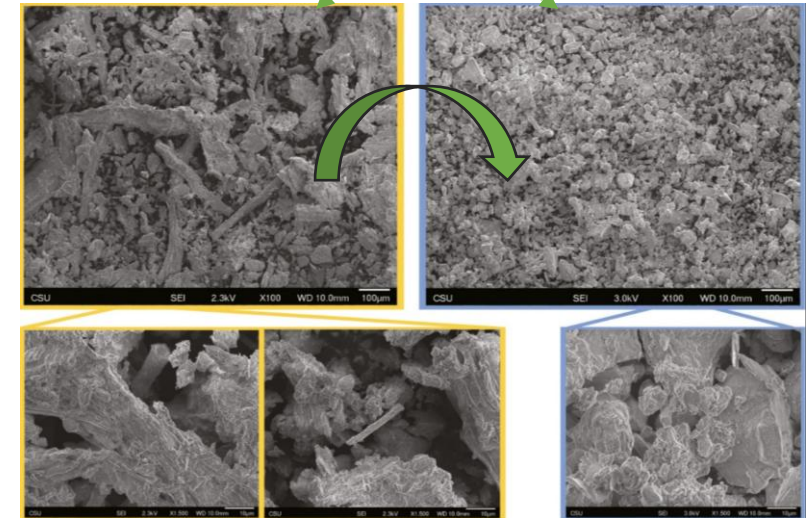
- Microbial C and N demand determined by growth and activity levels
- Controlled by environment conditions
- Greater microbial activity may stimulate C consumption → N mineralisation
  - E.g. high moisture + warm temperature



# Labile carbon availability

- Organic materials can vary in how easily degraded by microbes
- Soil organic matter stability –
  - Different pools of carbon more/less available to microbes
- Green manure vs. mature crop residues
  - More soluble sugars in immature residues → faster decomposition + N mineralisation

Plant inputs  
Shoots, roots, root exudates



Particulate organic matter

- Degrading plant fragments
- Faster turnover
- Available to microbes
- Simpler carbon forms

Mineral associated organic matter

- Bound to clay and silt
- Physically protected/stabilised

# How can soil health support N uptake?

- Soil health across physical, chemical and biological pillars
- Indirectly supports NUE and soil N cycling

## Alleviate soil constraints

- Greater crop N capture with improved vigour.
- E.g. compaction preventing root access to N in deeper layers.

## Adding amendments for carbon

- Supports soil biological activity and capacity.
- Diversifying N cycling pathways.

## Improving soil structure and water holding capacity

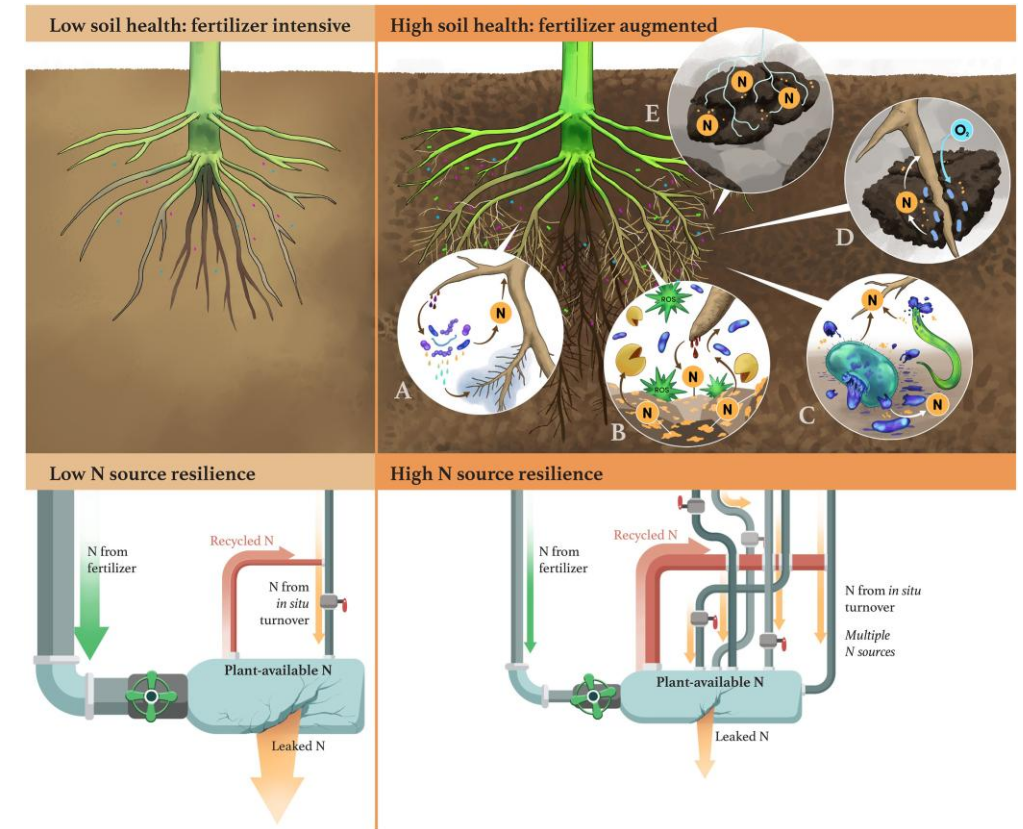
- Available moisture and oxygen supports N mineralisation.
- Reduce losses due to waterlogging.

## Using cover crops

- Capture excess N and slowly recycle to available forms.
- Add available carbon and nitrogen to soil.

# How can soil health support N uptake?

- Directly targeting nitrogen cycling via soil health
- Promote complexity in N cycling pathways
  - Resilience
  - Competition between loss vs. retaining N in soil
- Better match between crop N demand and supply via N cycling pathways



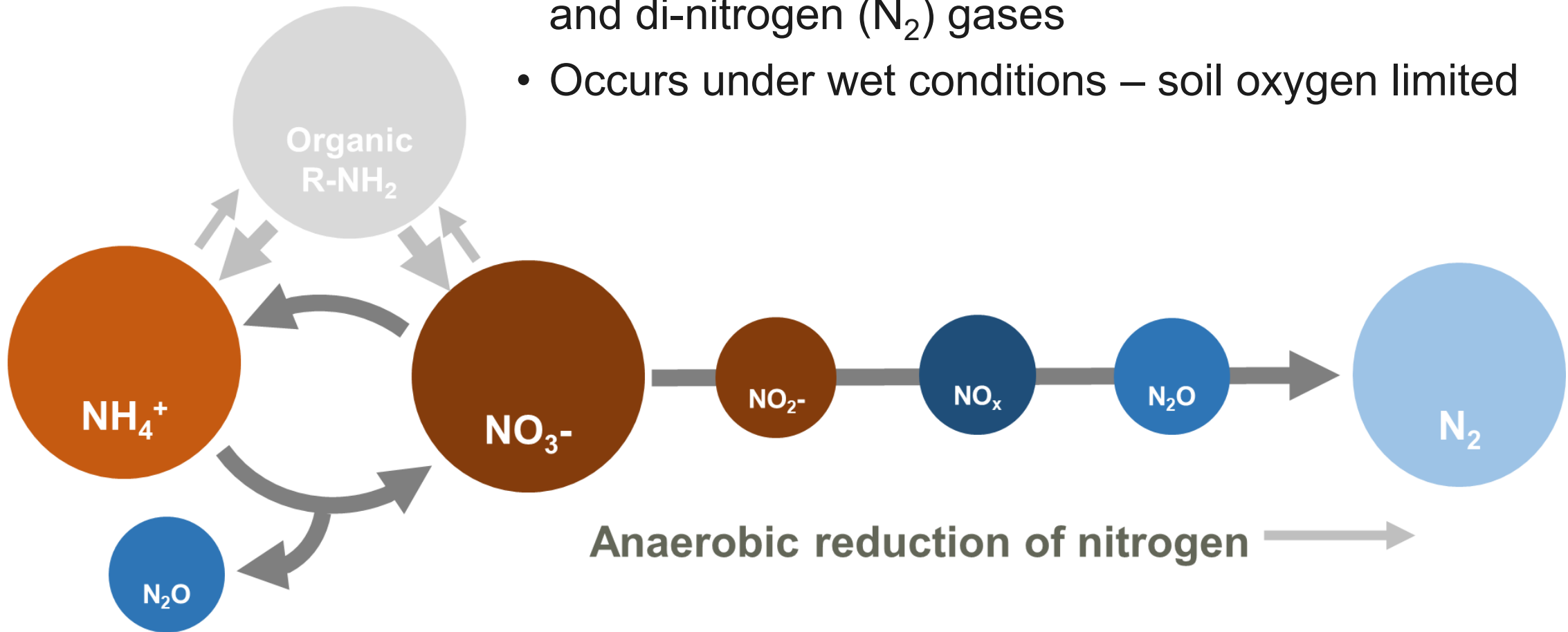
(Grandy et al. 2022, SBB)

# Can mineralisation replace fertiliser?

- Soil carbon implication
  - When nitrogen is separated from carbon, carbon lost as CO<sub>2</sub>
  - Relying on nitrogen mineralisation inherently 'burns' soil carbon
  - Rebuilding soil carbon requires both C and N
- Still need to replace nitrogen removed with harvest
  - Nitrogen fixation and organic amendments – might not keep up
- Might take a few years to see yield decline
- Balance yield/productivity with soil health goals


# Risks of nitrogen loss – denitrification

- Denitrification – loss of nitrogen to nitrous oxide ( $\text{N}_2\text{O}$ ) and di-nitrogen ( $\text{N}_2$ ) gases
- Occurs under wet conditions – soil oxygen limited



# South-east Queensland – ‘perfect storm’ for denitrification

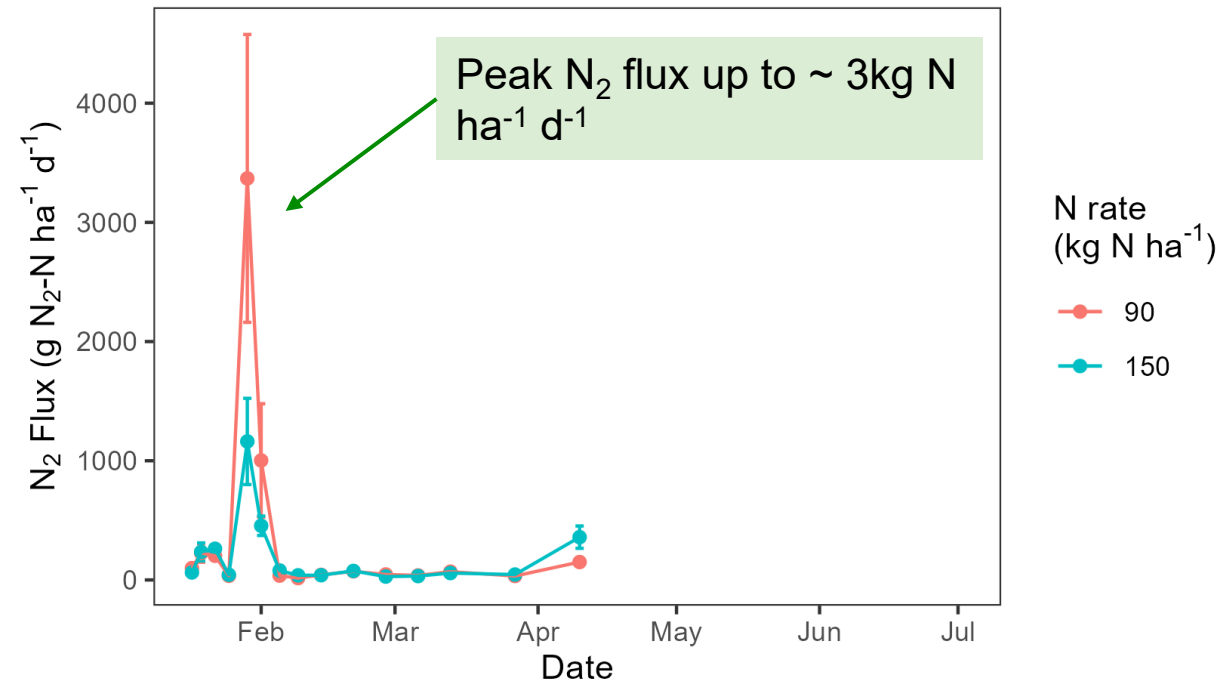
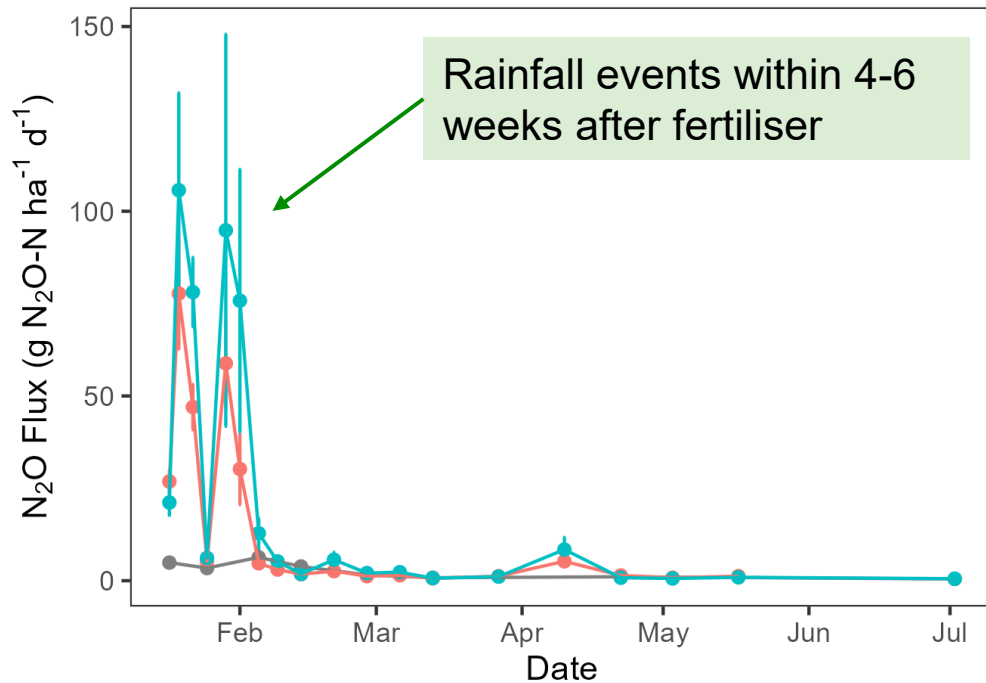
- Conditions that promote denitrification:
  - Large nitrate pool
  - Saturated to waterlogged conditions
  - High clay content
  - High temperatures
  - Labile carbon



E.g. Fertiliser applied before summer crop, followed by large rainfall event

# Losses of nitrogen to denitrification

- Denitrification in summer sorghum crop at Gatton
- Cumulative losses 20-35 kg N ha<sup>-1</sup>

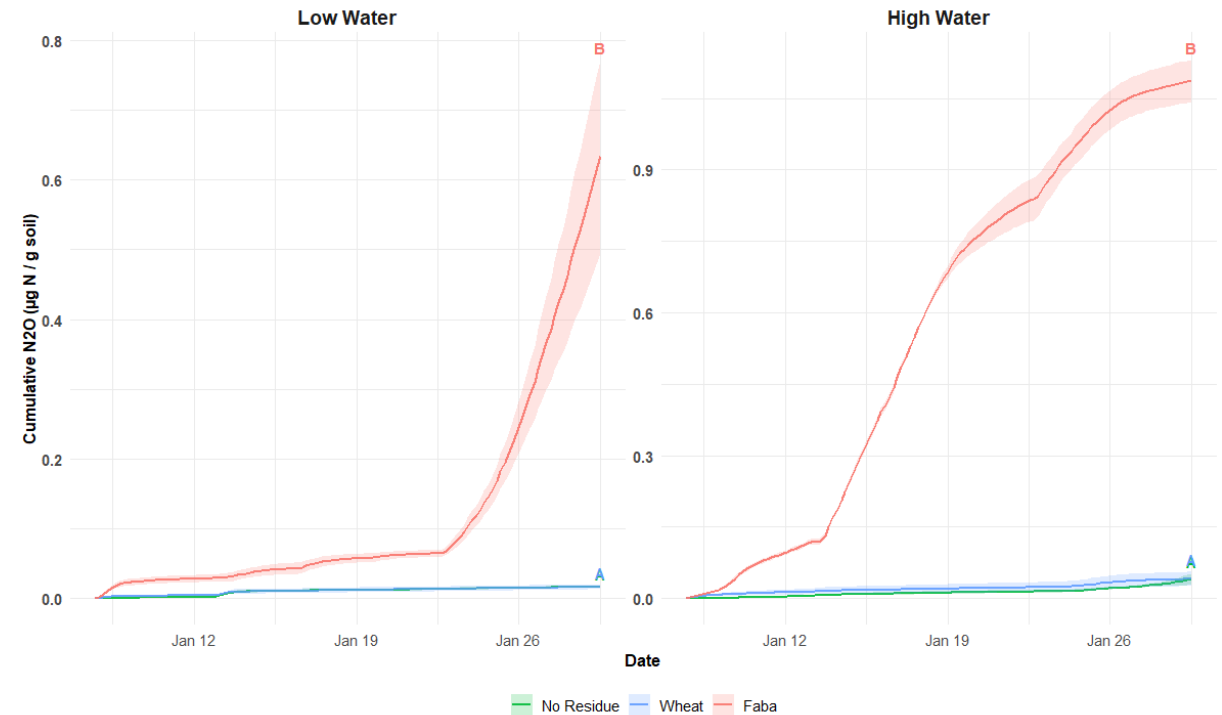


# How to reduce denitrification losses

- Avoid high soil mineral N coinciding with waterlogging and warm temperatures
- Strategies include:
  - Split fertiliser applications
  - Fertiliser timing relative to rainfall
  - Consider banding or inhibitor products to slow nitrate formation

# Does carbon have a role in denitrification?

- Carbon can act as a fuel to denitrification
  - Energy source for microbes undertaking denitrification
- Alternatively, carbon reduce nitrate-N via immobilisation
  - Reduce mineral N availability – thereby reduce loss to denitrification
  - E.g. N<sub>2</sub>O emissions from faba bean vs. wheat residues



# Summary

- Mineralisation/immobilisation are key controls on soil N supply.
- Soil provides 50-80% of plant nitrogen, even if fertiliser applied.
- Mineralisation amount determined by relative availability of C and N.
- Improving soil health can diversify nitrogen cycling and improve N capture.
- Managing fertiliser to avoid high nitrate with saturated soil to reduce losses.

# Thank you!

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## *Funding*



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