Nutrient supply at the farm scale – challenges and solutions.

Christine Watson
Kairsty Topp, Robin Walker, SRUC
Melanie Karlsson, Henrik Smith, Lund University
Rafaelle Reumaux, Sigrun Dahlin, Johanna Wetterlind, Göran Bergkvist, Ingrid Öborn, SLU

Current regulatory framework & principles for N supply and management

EC Reg 848 with 2023 revisions

Article 5 general principles

(g) the restriction of the use of external inputs; ….limited to:

(i) inputs from organic production; ….

(ii) natural or naturally-derived substances;

(iii) low solubility mineral fertilisers;

Part I: Plant production rules

1.9.2. The fertility and biological activity of the soil shall be maintained and increased:

(a) except in the case of grassland or perennial forage, by the use of **multiannual crop rotation** including **mandatory leguminous crops** as the main or cover crop for rotating crops and other green manure crops;

(b) in the case of greenhouses or perennial crops other than forage, by the use of short-term green manure crops and legumes as well as the use of plant diversity; and

(c) in all cases, by the **application of livestock manure or organic matter, both preferably composted**, from **organic production**.

1.9.8. **Mineral nitrogen fertilisers shall not be used**.

List of “approved” products and interpretation ……within and between countries

Principles into practice……

Need to replace what is sold off

Aim to build soil fertility (needs C and N)

N fixation via legumes

Rotational supply of N via crop residues

On-farm manures

Off-farm sources (manure and other)

N input sources organic farming – likely reliance

System	N fix grain legumes	N fix forage legumes	Feed imports	Manure (imports)	Other N inputs
Pig/poultry only			+++		
Grass/legume based ruminant		+++	(+++)		
Crop/livestock	+	++	++		
Crop only (manure)	++	(++)		++	+
Crop only (no manure)	+++	(++)			+++

Studies estimating dependence of organic farming on external nutrients vs BNF

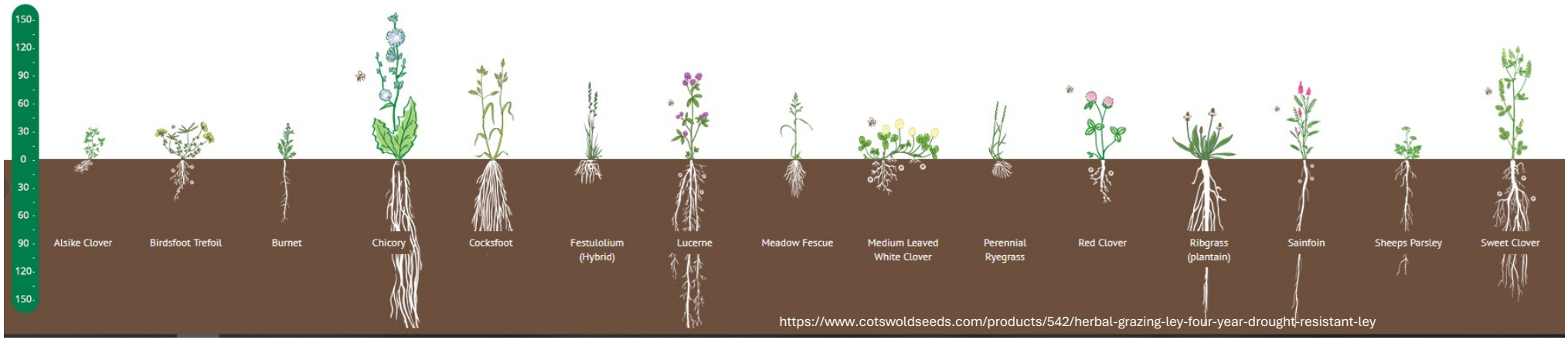
Study	% N inputs from BNF	N input from external nutrients (% total inputs)	Conventional manure use (*recalculated from paper)	Scale of study
Vergely et al. 2024	53%	20% from feed and conventional manure	11 kg N/ha/yr	Modelled N flows in France in 2021
Reimer et al. 2023	50%	16-19% from manure and digestates from conventional farms	14 kg N/ha/yr	71 farms, 8 European countries
Nowak et al. 2013	63%	23% conventional manure, forage, straw	20 kg N/ha/yr*	63 organic farms in 3 districts of France
Kyed et al. 2006			24 kg N/ha/yr	Danish organic land (177,000 ha)
Berry et al. 2003	35-46% stockless 70% stockless			9 organic farms, UK

How can we achieve **sustainable** nutrient management in organic farming?

- Rotational design approach
- Crop/livestock integration
- ”Conventional” input approach?
- Achieving synchrony – supply and demand

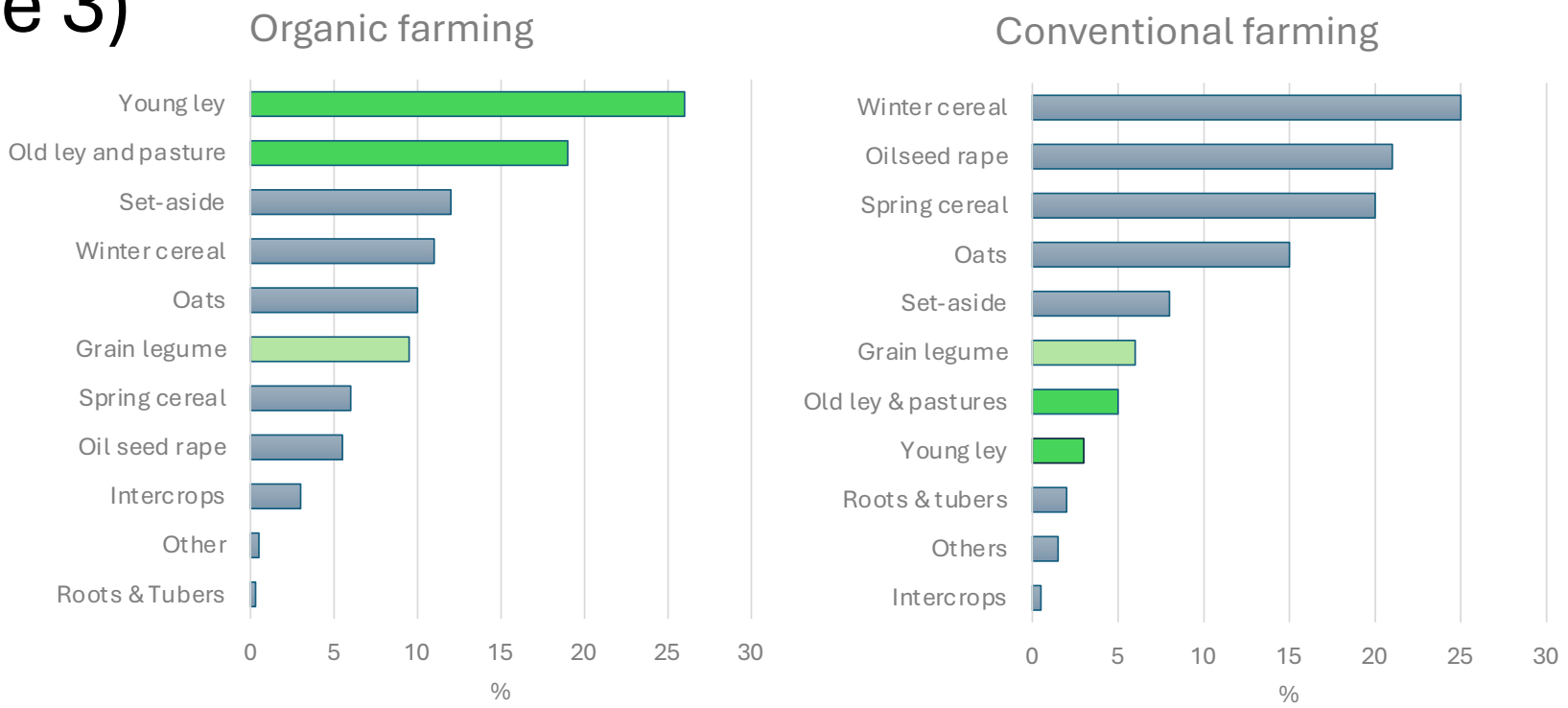
Rotation design – what tools do we have?

- Crop sequences (“pre –crops” and “post-crops”) of cash crops
- Service crops – many options to introduce annual and perennial species
- Crop mixtures – common to have species and variety mixes in grassland. Not so common (but possible) in combinable crops.



Rotational approach

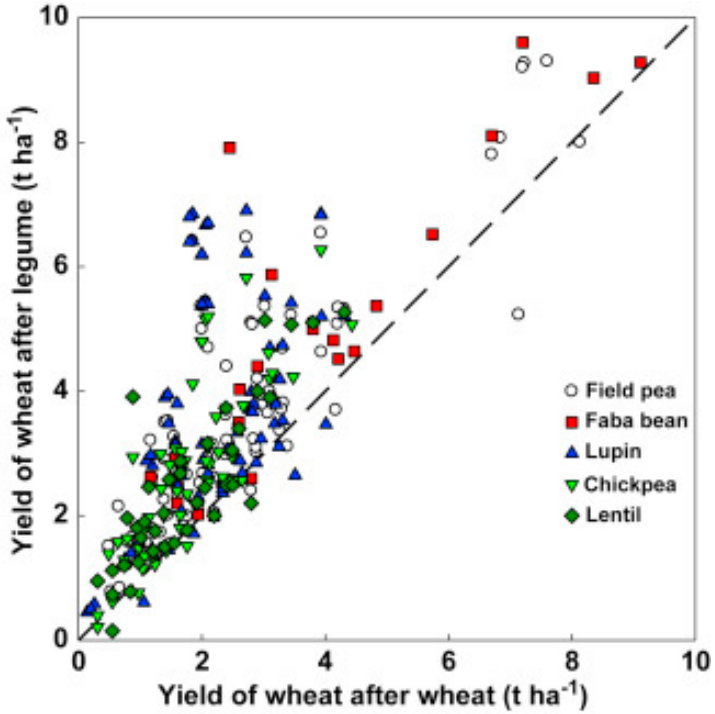
Where do the high value/N demanding crops fit? Pre-crops to Winter wheat in Sweden (Production Zone 3)

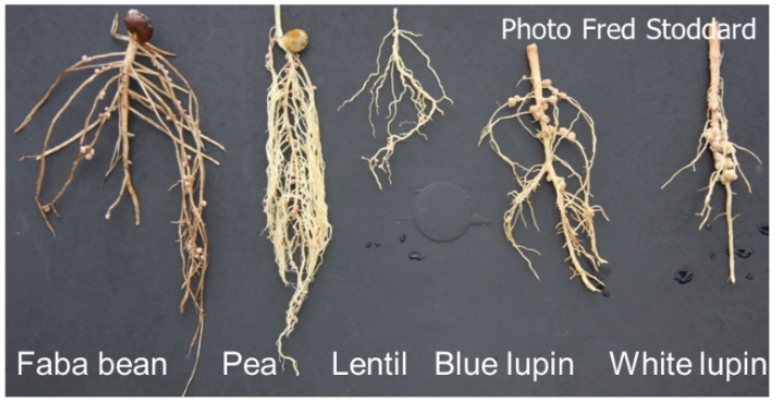


Redrawn from Reumaux et al 2023. (LPIS field data EU IACS crop sequences on arable land in Sweden (2005–2014))

Rotational approach

Utilising grain legumes in crop rotations



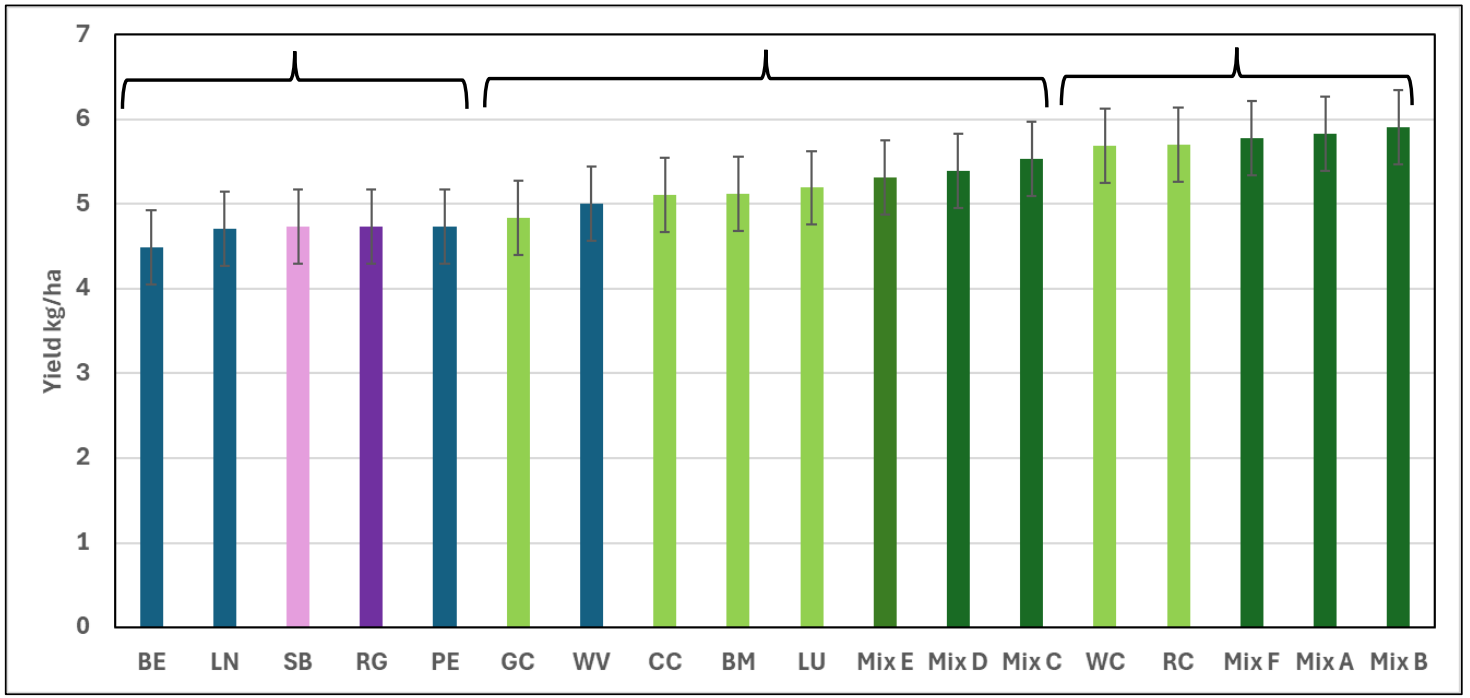


The dashed line represents equal yields. Any points above the dashed line indicate yield improvements when a legume is the preceding crop. Fitted regression: Grain yield (wheat after legumes) = 0.92 + 1.06 x (wheat after wheat) [r2 = 0.69].

Peoples, M.B. et al. 2019. The contributions of legumes to reducing the environmental risk of agricultural production. In Agroecosystem diversity (pp. 123-143). Academic Press.

Rotational approach

Impact of pre-crop on yield (+/- SED) of following spring barley, Scotland (Watson, Topp & Walker unpublished)



BE– Spring beans
LN– Lupins
PE- Spring peas
WV- Winter vetch

SB– Spring barley
RG– Ryegrass
WC- White clover
RC – Red clover

GC- Grass/white clover
CC- Crimson clover
BM- Black medic
LU - Lucerne

Mix A- RC/BM/LU
Mix B– RC/WC/CC
Mix C- WC/WV/PE

Mix D –WC/WV/BE
Mix E – WC/BM/WV
Mix F –WC/BM/LN

Rotational approach

Using plant functions to manage N in organic farming - examples

- Reduced urinary N excretion in cattle fed Plantago lanceolata (Cheng et al. 2017) and Lotus corniculatus (Woodward et al. 2009)
- Slower nitrification of sheep urine N in soil from sheep fed Plantago lanceolata (Judson et al. 2019)
- Use in pastures or perhaps as undersown species or within cover crops mixtures?

Cheng et al. 2017 https://doi.org/10.1016/j.anifeedsci.2017.04.023
Judson et al 2019 https://doi.org/10.33584/jnzg.2018.80.335
Woodward et al. 2009 Proceedings of the New Zealand Society of Animal Production 2009. Vol 69: 179-183

Trend towards food systems with less livestock products?

The Guardian

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Plant-heavy 'flexitarian' diets could help limit global heating, study finds

Global adoption of diet low in meat would aid health, land and food systems as well as reducing emissions, researchers say

A global shift toward plant-heavy diets could help restrict heating to 1.5C, researchers find. Photograph: KateSmirnova/Getty Images/iStockphoto

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'Bewildering' to omit meat-eating reduction from UN climate plan

Academic experts also criticise UN Food and Agriculture Organization for dismissing alternative proteins

Many of the recommendations involved intensifying the efficiency of animal farming techniques. Photograph: Reuters/Alamy

INDEPENDENT

Climate change leading to food price volatility, campaigners warn

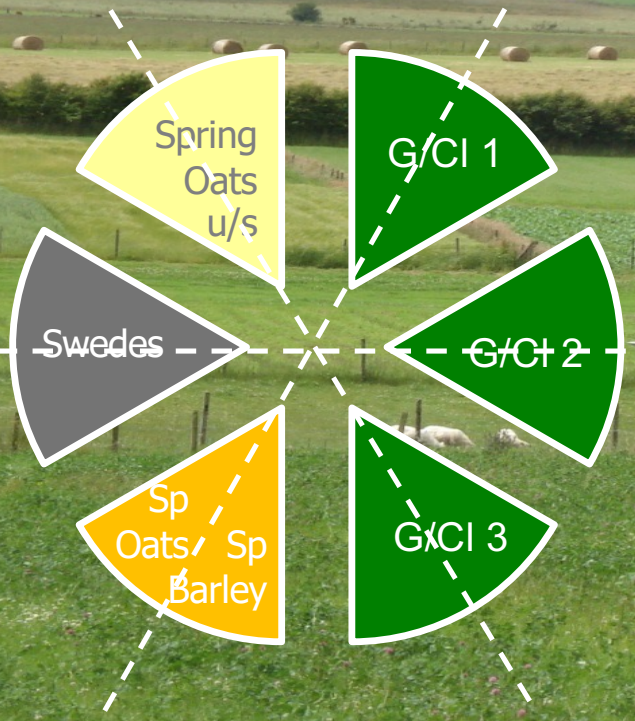
Food Foundation executive director Anna Taylor said the 'failures' of the current food system were being felt by both farmers and consumers.

Josie Clarke • Thursday 09 May 2024 13:58 BST

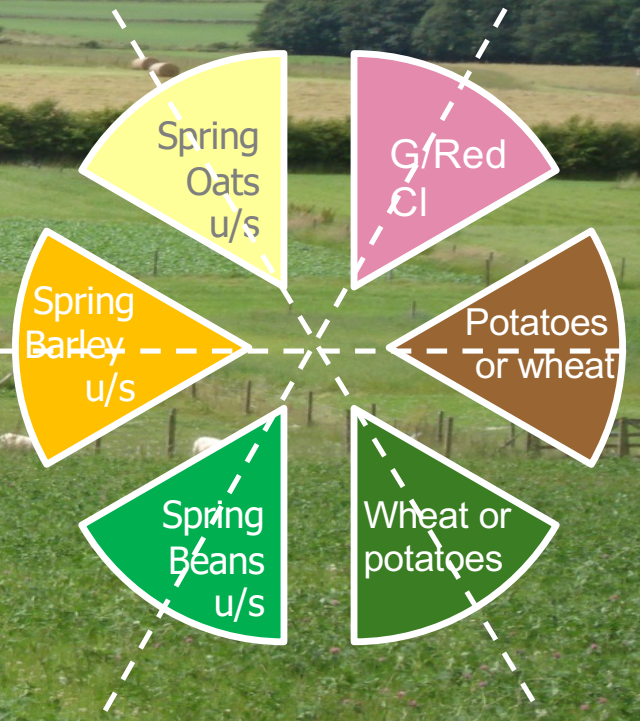
An unprecedented wet winter has meant many farmers have been unable to plant or apply fertiliser (Joe Giddens/PA) *(PA Wire)*

Tulloch Organic Rotation Phase 2

T50
1991-date



Plant based (stockless)
2007-2022



HEALTHY SOILS FOR A GREEN RECOVERY

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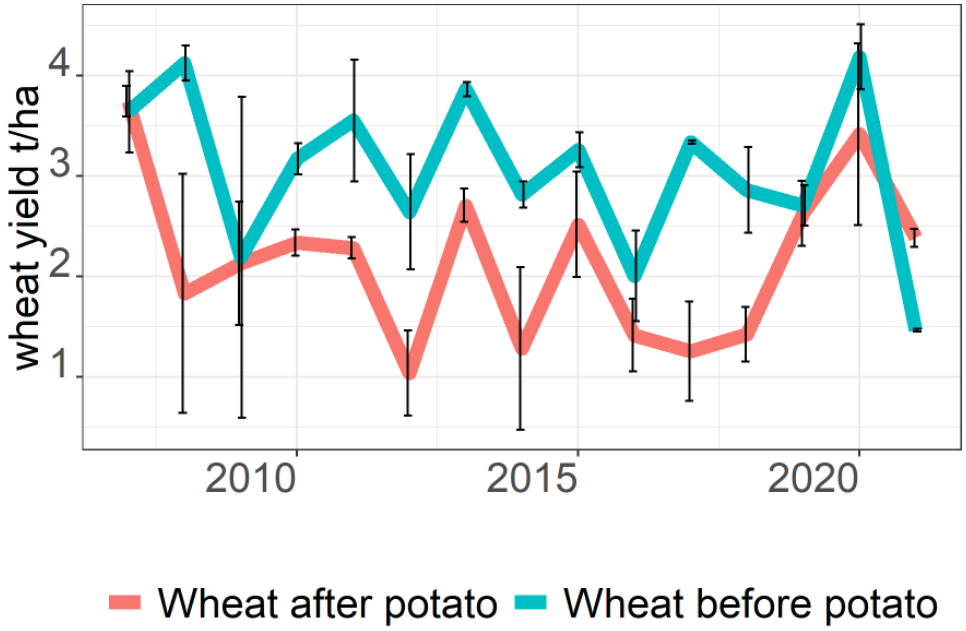
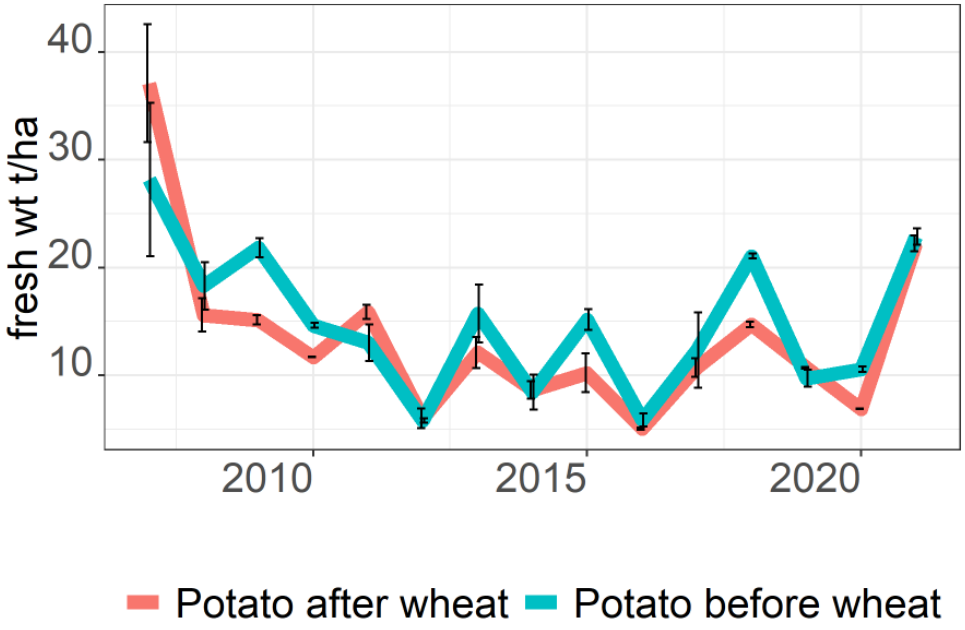
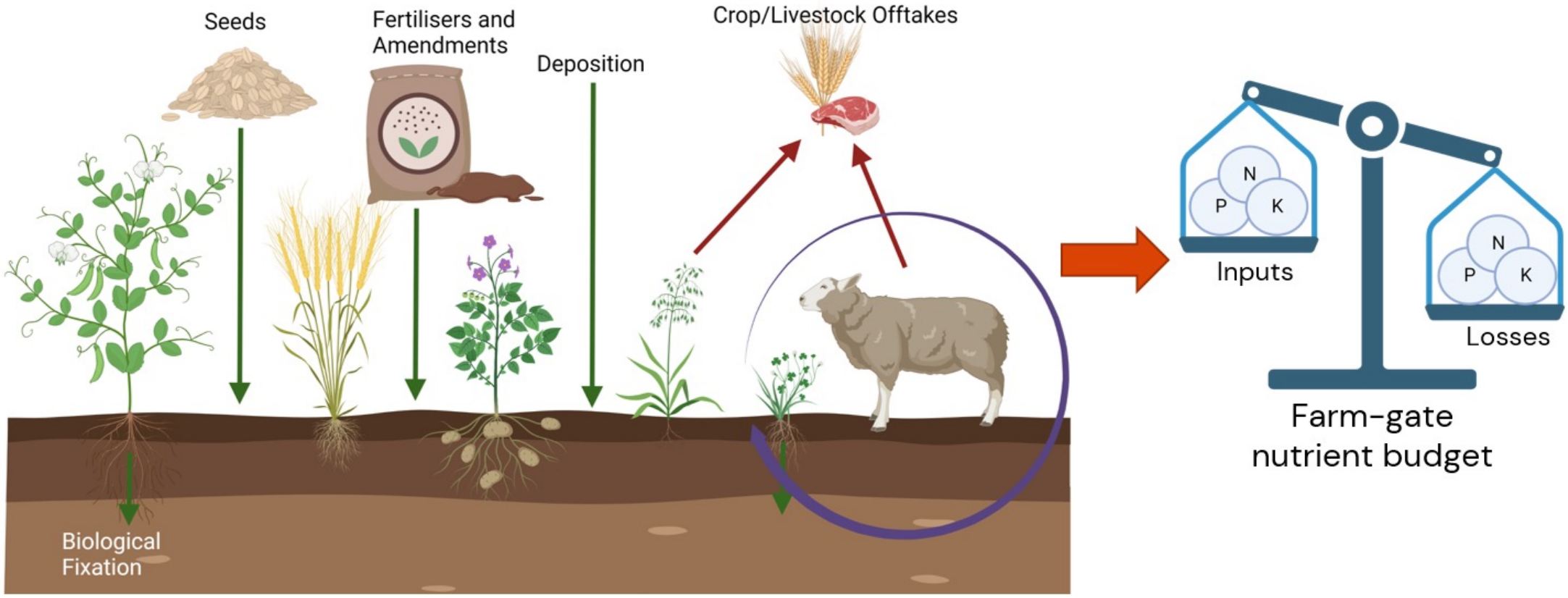
Rotational approach

Crop sequence effects on yield – Phase 2





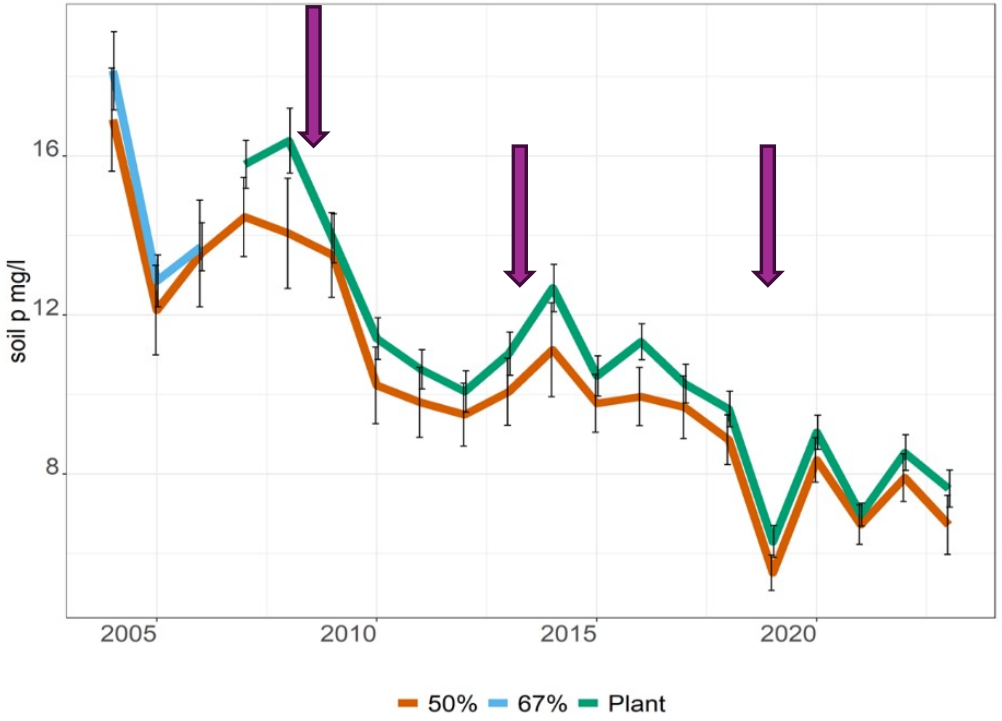
Farm-Gate Nutrient Budgets for the Organic Rotations



Created by Catriona Willoughby 2021 using Biorender.com

Nutrient Budget - Phosphorus

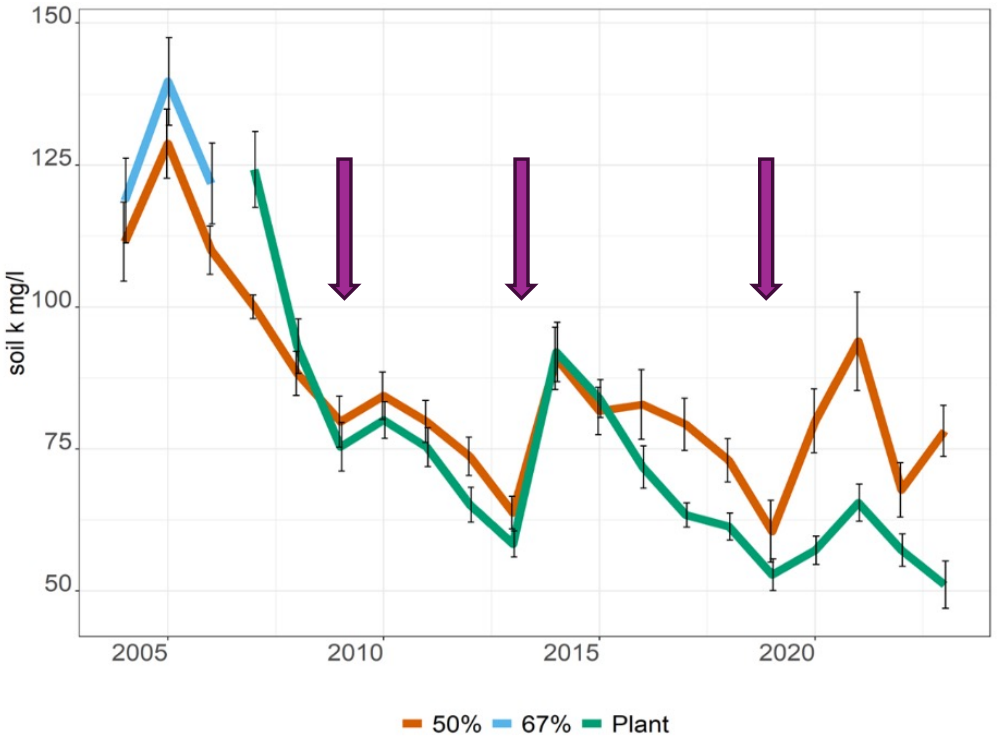
Phosphorus	Mixed	Plant based
Total P inputs kg/ha	**12**	**3**
Total P offtake kg/ha	13	9
P balance kg/ha	**-1**	**-6**
Offtake as % of input	108	300
Balance as % of input	**-8.3**	**-200.0**



Willloughby et al. 2022 https://doi.org/10.1002/fes3.427

Nutrient Budget - Potassium

Potassium	Mixed	Plant based
Total K inputs kg/ha	33	13
Total K offtake kg/ha	**46**	**23**
K balance kg/ha	-13	-10
Offtake as % of input	**139.4**	**176.9**
Balance as % of input	**-39.4**	**-76.9**



Willoughby et al. 2022 https://doi.org/10.1002/fes3.427

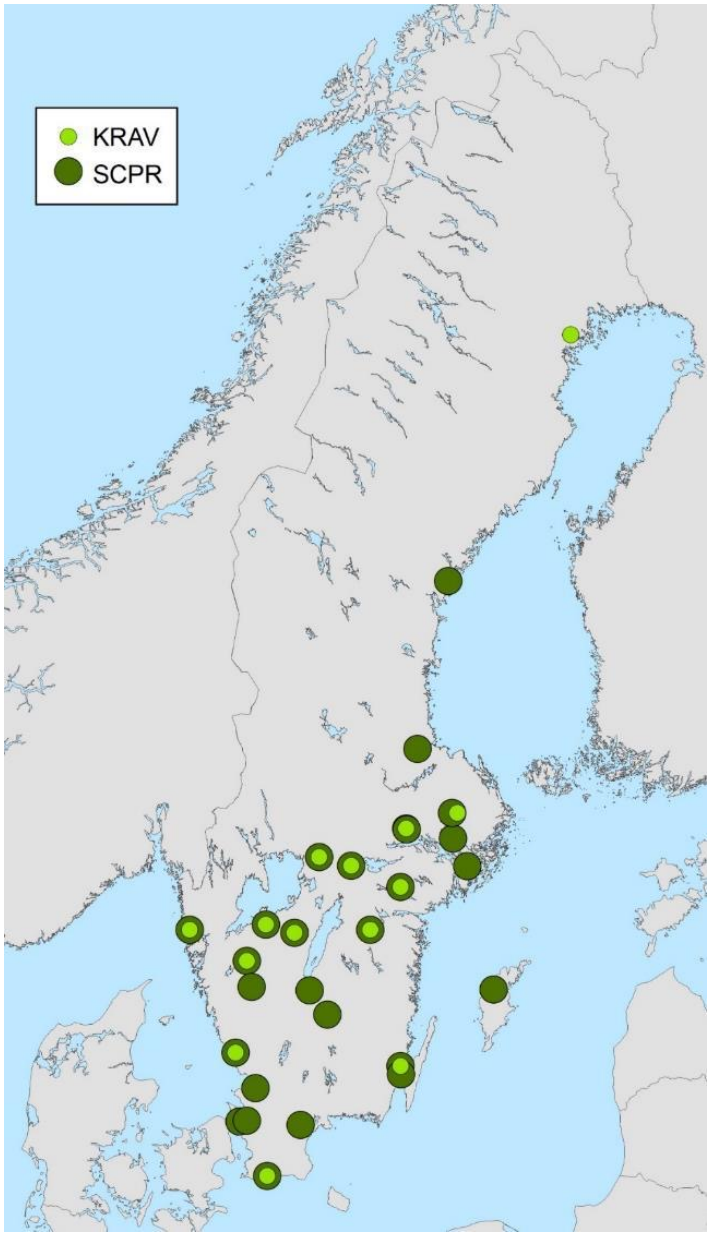
“Conventional” input approaches

Input approach

Locally available inputs - certified biogas plants Sweden

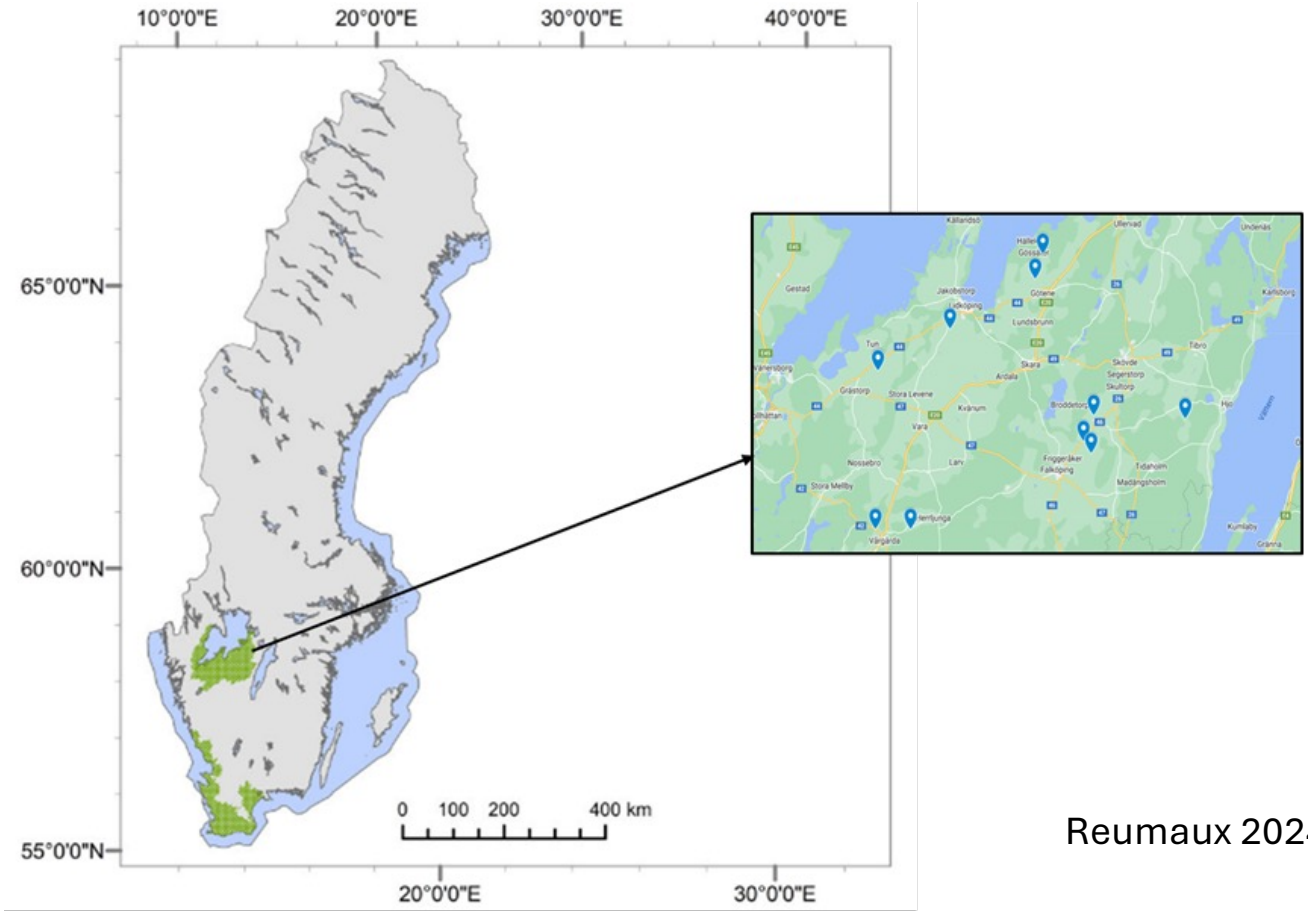
- In 2021, there were 27 certified biogas plants in Sweden
- 14 plants are KRAV certified

- KRAV 12.3.10
  "At least 5% of the substrate added to the biogas plant on an annual basis must come from fertiliser, ley or other organic material from organic production or production in conversion to organic."
  https://www.krav.se/en/standards/



Input approach

Using digestate to boost yield and grain N

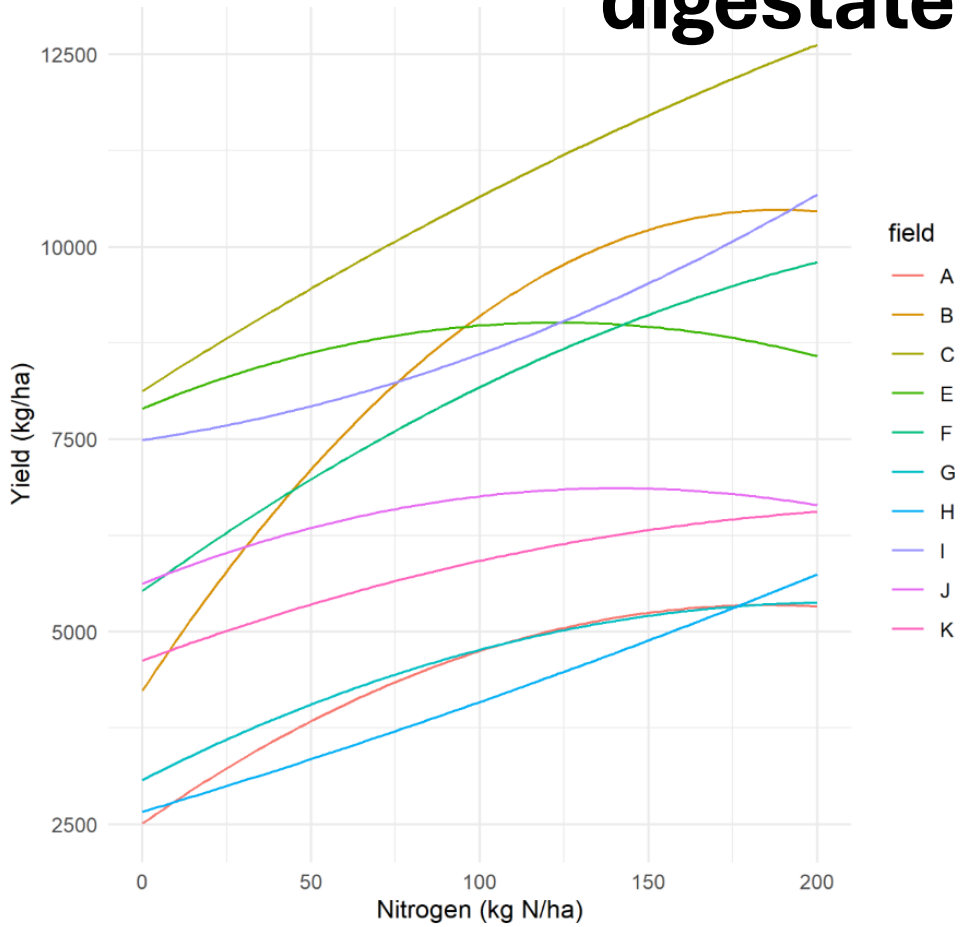


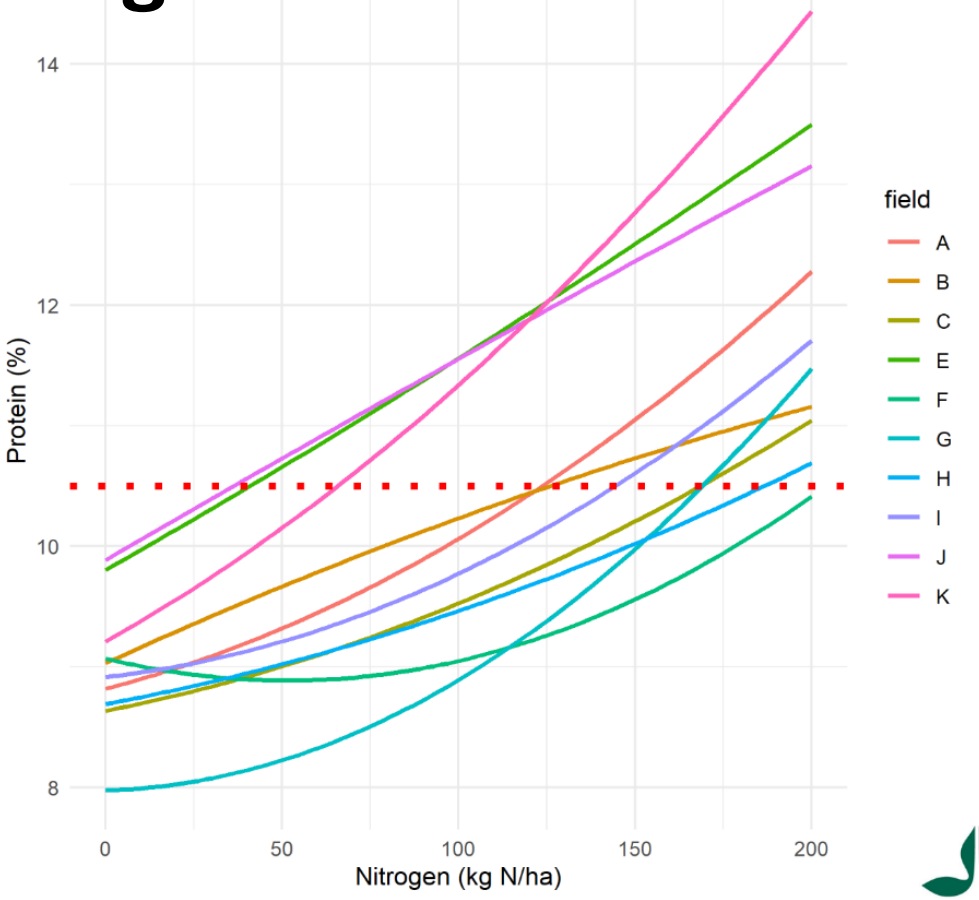
10 organic farms with local KRAV certified biogas (no animal residues)

Reumaux 2024 PhD Thesis

Input approach

Yield and protein response to biogas digestate in organic winter wheat





10 organic farms

Reumaux 2024 PhD Thesis

Input approach – precision ag

Precision approaches to nutrient supply in organic farming

Remote sensing data used to estimate

- Pre-crop growth (A)
- Spring wheat growth (B) (C)
- Soil properties like clay content (D)

Precision agriculture for organic farming

- Apply nutrients to overcome variability?
- Embrace variability and use different crops?

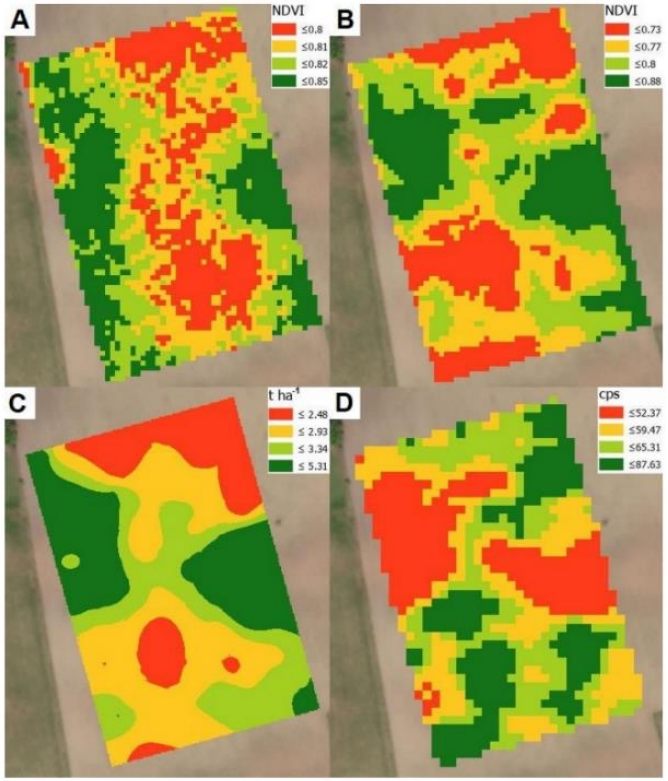


Figure 3. Maps showing field variation patterns of NDVI from the Ley in the 2021 season (A), NDVI from the spring wheat in the 2022 season (B), unfertilized grain yield, extrapolated from control plots (C) and ^{232}Thorium gamma radioactivity (D).

Reumaux 2024 PhD Thesis

But it’s about so much more than just Nitrogen or production……

Managing losses
GHGs

C:N ratios
Contaminants

Soil health and fertility

P, K & other nutrients

A forward look.....

- If organic farming is to grow and develop, we need to work on the nitrogen (nutrient) supply issues
- Need to meet contemporary issues head on, including
  - dietary change impacts
  - contribution to climate change mitigation
  - changing contaminants
  - consumer acceptance
  - environment and biodiversity
- Soil health is a key component of this story
- Using crop functions to design more N efficient systems e.g. BNI inhibitors
- New technology – precision ag, food technology
- It's never just a Nitrogen story – C, P, K and other nutrients

Acknowledgements

FORMAS

Mi Bicycle
MItigation and adaption through better BIomass CYcling in Crop Livestock systems of north and western Europe

SusCrop – ERA-NET
Cofund on Sustainable Crop Production
FACCEJPI

HEALTHY SOILS FOR A GREEN RECOVERY

INTERCROP VALUES

MIXED
EFFICIENT AND RESILIENT MIXED FARMING & AGROFORESTRY

Horizon 2020 Grant agreement No 862357

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