The future of responsible plant nutrition

Achim Dobermann

Chief Scientist

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Collaborative Workshop of ERA-Net ICT-AGRI and MANUFUTURE AET
10 November 2023, Hannover, Germany

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VDI Wissensforum

2020s

- 8 billion people - 100 million t of fertilizer N (crops)
- ‘Gray’ nitrogen
- Bulk fertilizers + empirical advice + mechanized/manual application
- Global NUE on cropland ~55%
- Leaky nutrient cycles
- Nutrient imbalances (soil health) & hidden hunger (micronutrients)

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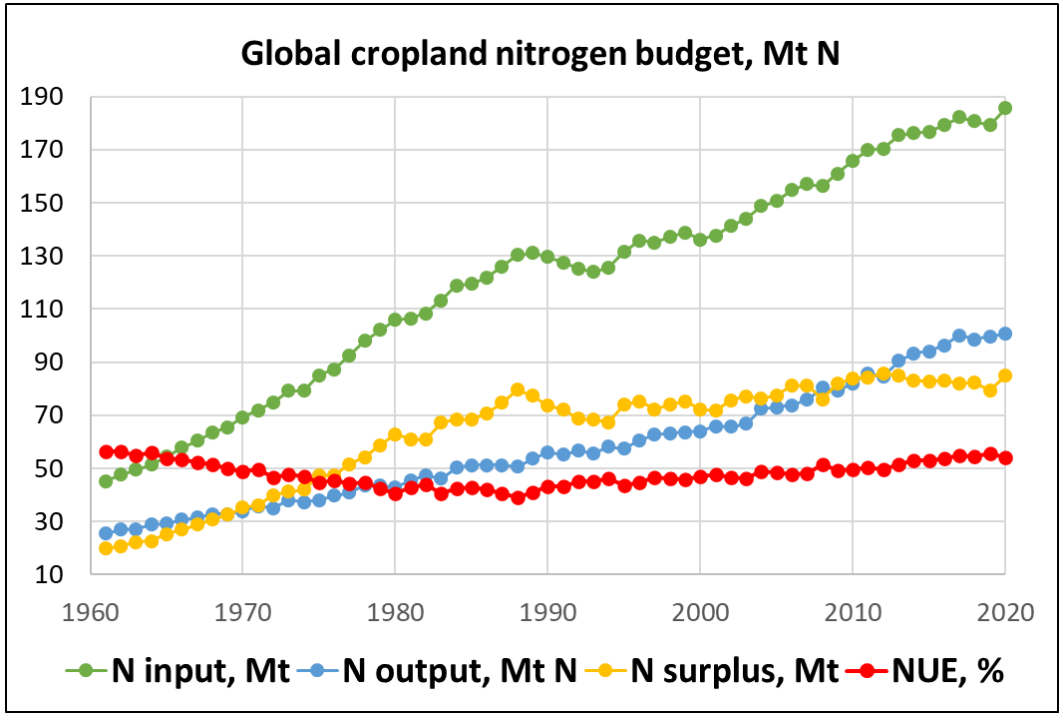
Decoupling agricultural and fertilizer growth



$$NUE = \frac{N\ output}{Sum\ of\ N\ inputs}$$

Fertilizer-N
+ Manure-N recycled
+ Crop BNF
+ Atmospheric deposition
+ (irrigation, biosolids…)

Source: FAO-IFA Cropland nutrient budget database
https://www.fao.org/faostat/en/#data/ESB

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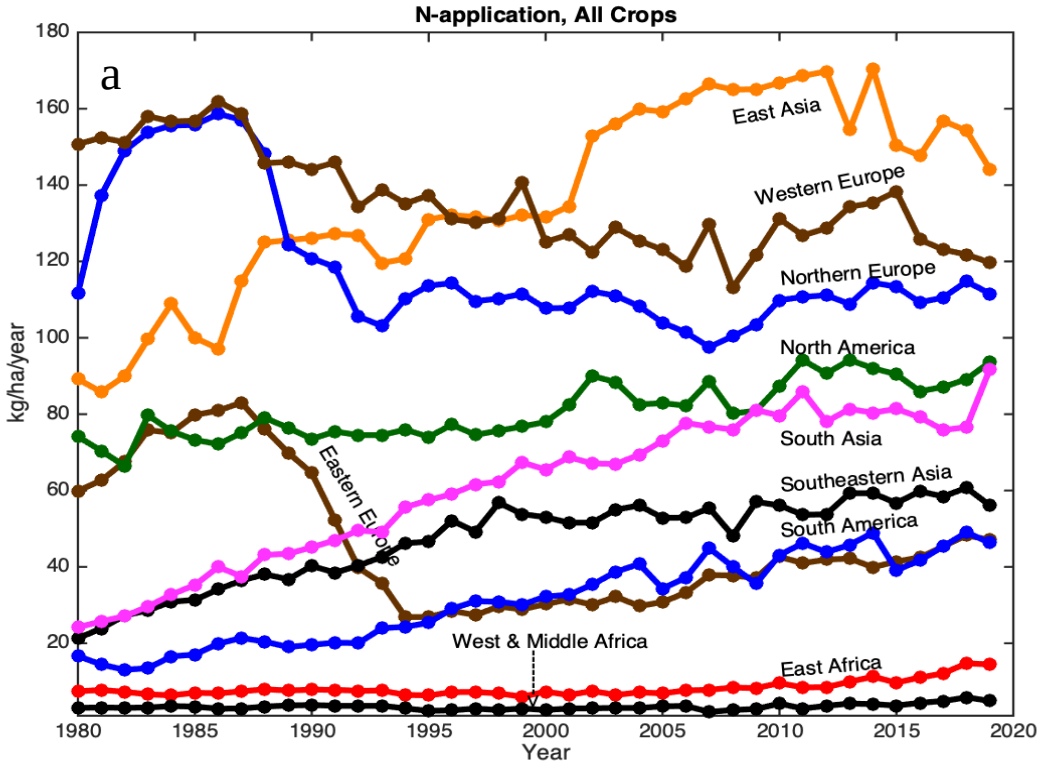
The world is moving at different pace



Average N-fertilizer application rate on cropland, 1980-2019
(Deepak Ray et. al., unpublished)

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Global long-term fertilizer demand increase until 2050

Nutrient	High efficiency + high recycling (%/year)	Business as usual (%/year)
Nitrogen	0.7	1.1
Phosphorus	1.0	1.3
Potassium	1.1	1.8

Primarily in Asia, South America and Sub-Saharan Africa

Fertilizer industry has to strike a balance between food security and environment

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Responsible plant nutrition

Global Food Security 33 (2022) 100636

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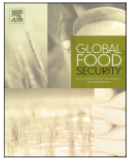
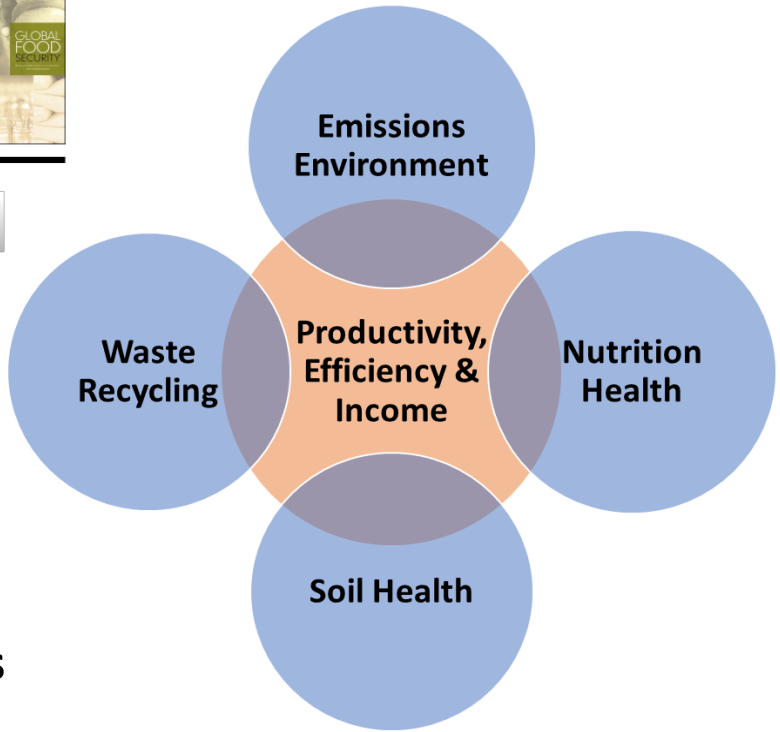
journal homepage: www.elsevier.com/locate/gfs



Responsible plant nutrition: A new paradigm to support food system transformation

Achim Dobermann [a,*], Tom Bruulsema [b], Ismail Cakmak [c], Bruno Gerard [d], Kaushik Majumdar [e], Michael McLaughlin [f], Pytrik Reidsma [g], Bernard Vanlauwe [h], Lini Wollenberg [i], Fusuo Zhang [j], Xin Zhang [k]

https://doi.org/10.1016/j.gfs.2022.100636



Food systems approach
Circular economy
Sustainable farming & business
Innovation

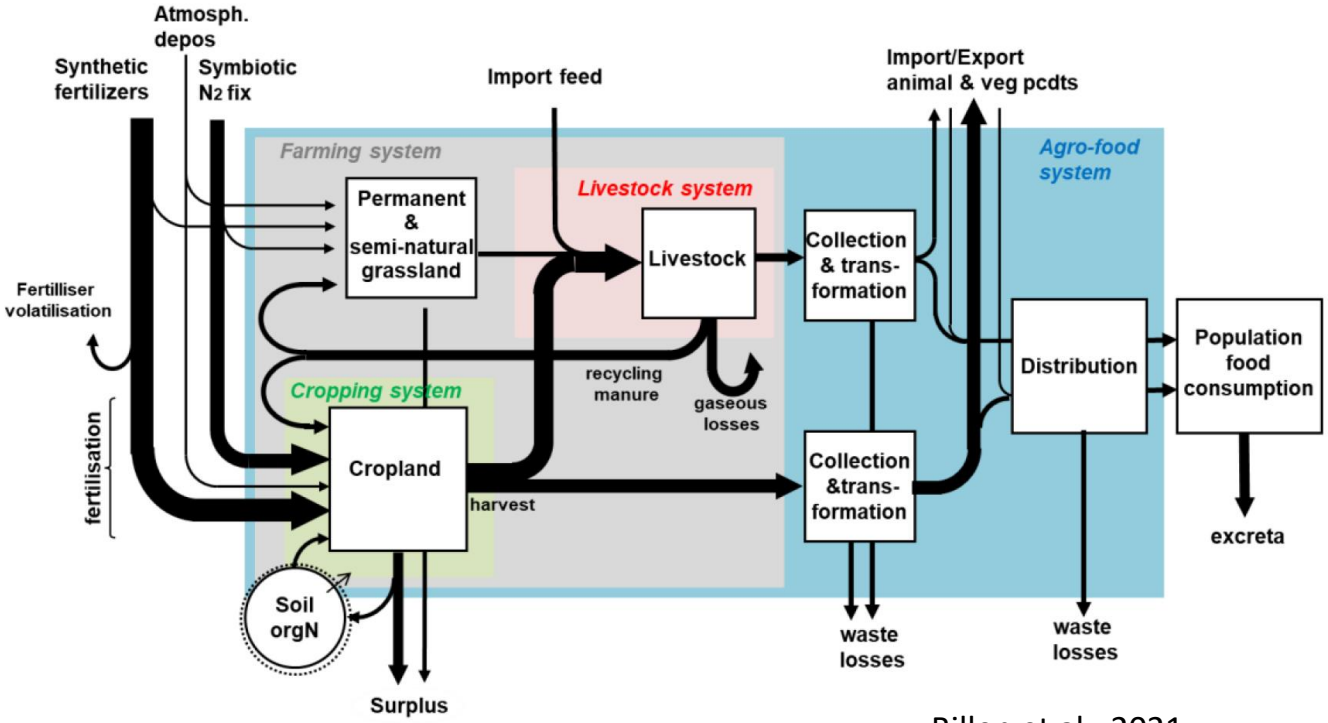
SCIENTIFIC PANEL
ON RESPONSIBLE PLANT NUTRITION

https://www.sprpn.org

Agro-food systems in terms of nutrient flows

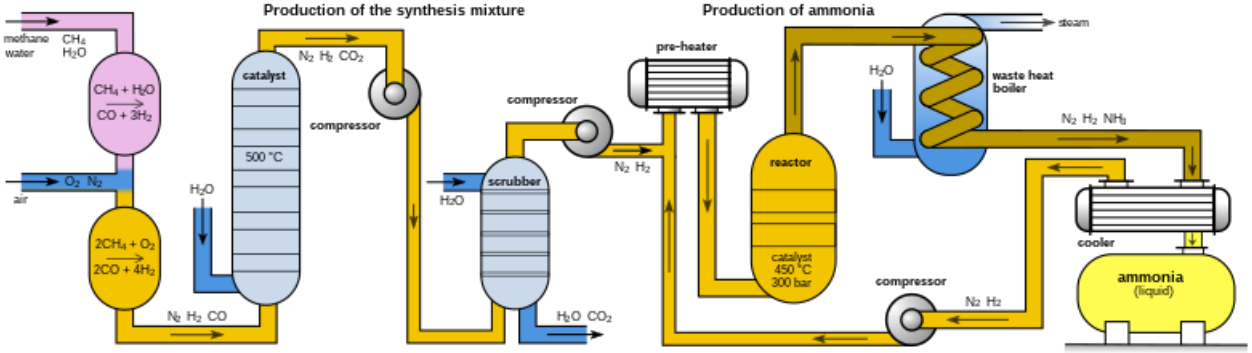
Key innovation areas:

1. Low-carbon fertilizers
2. Better fertilizers
3. Precise nutrient management
4. Nutrient recovery & recycling
5. Agronomic practices



Billen et al., 2021

Haber-Bosch: 'Gray' ammonia



- ~50% of the N found in humans
- ~185 Mt NH_3 each year, 20% industrial use
- ~500 plants in ~65 countries
- Big plants: 2000-3000 tons NH_3 per day
- **2% of energy use, 1.5% of GHG emissions**

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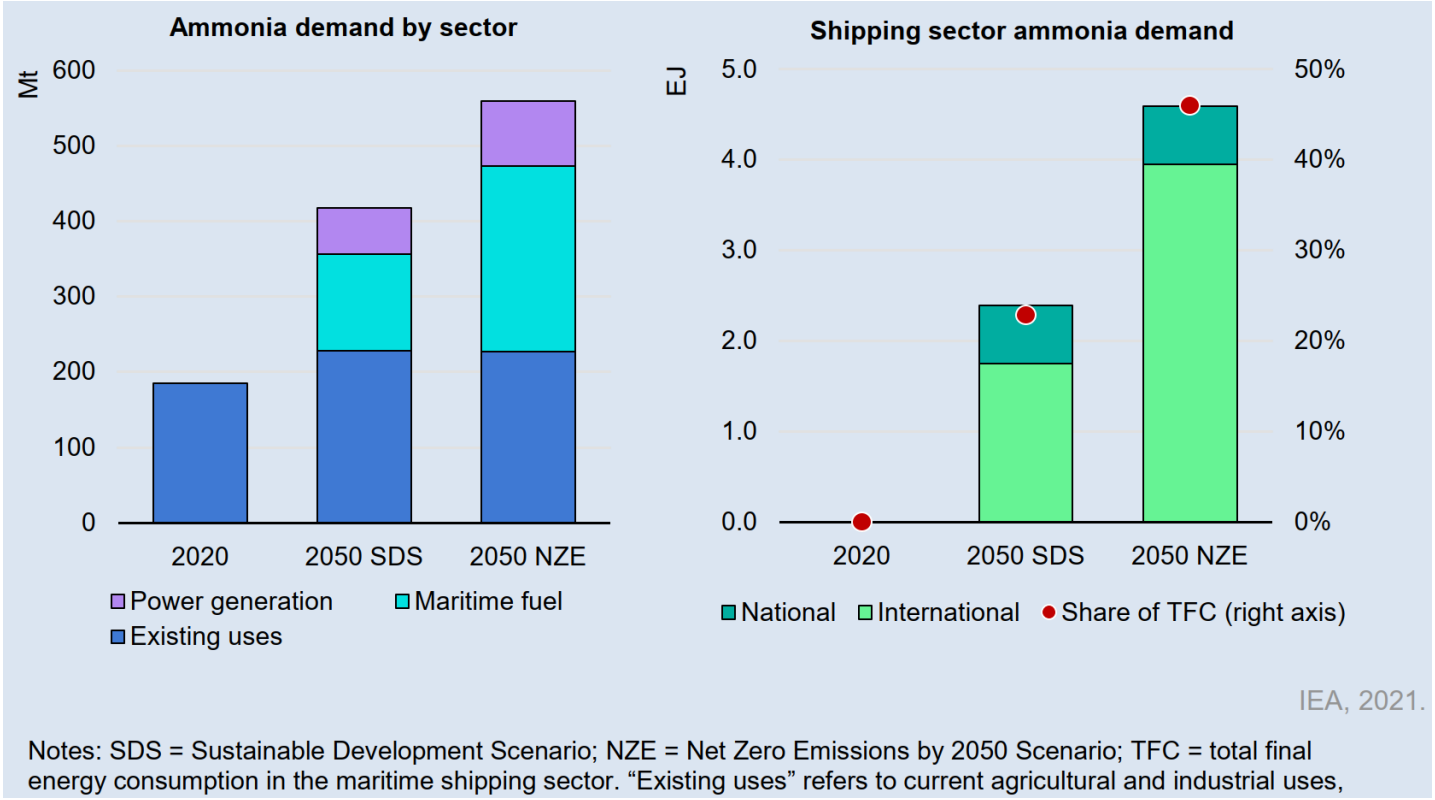
Massive increase in future demand for (low-carbon) ammonia



IEA, 2021.

Notes: SDS = Sustainable Development Scenario; NZE = Net Zero Emissions by 2050 Scenario; TFC = total final energy consumption in the maritime shipping sector. "Existing uses" refers to current agricultural and industrial uses,

https://www.iea.org/reports/ammonia-technology-roadmap

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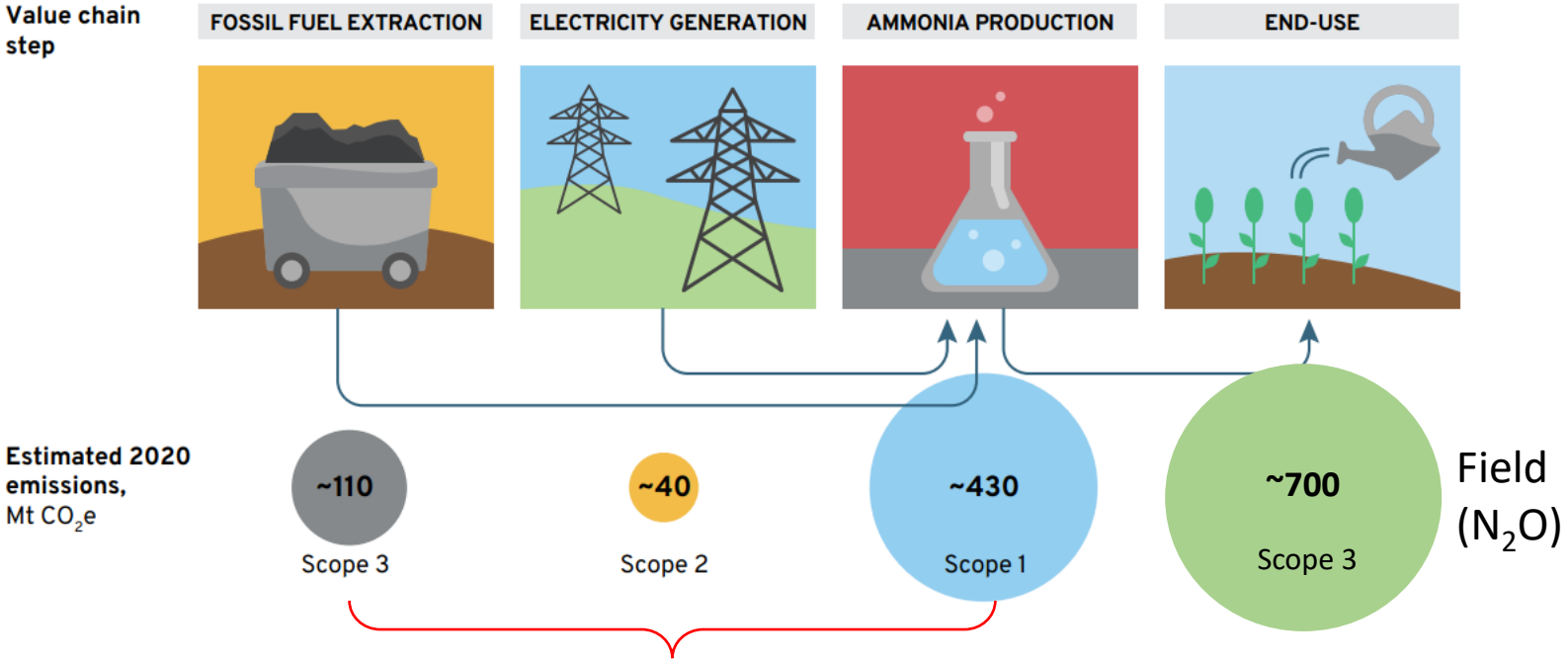
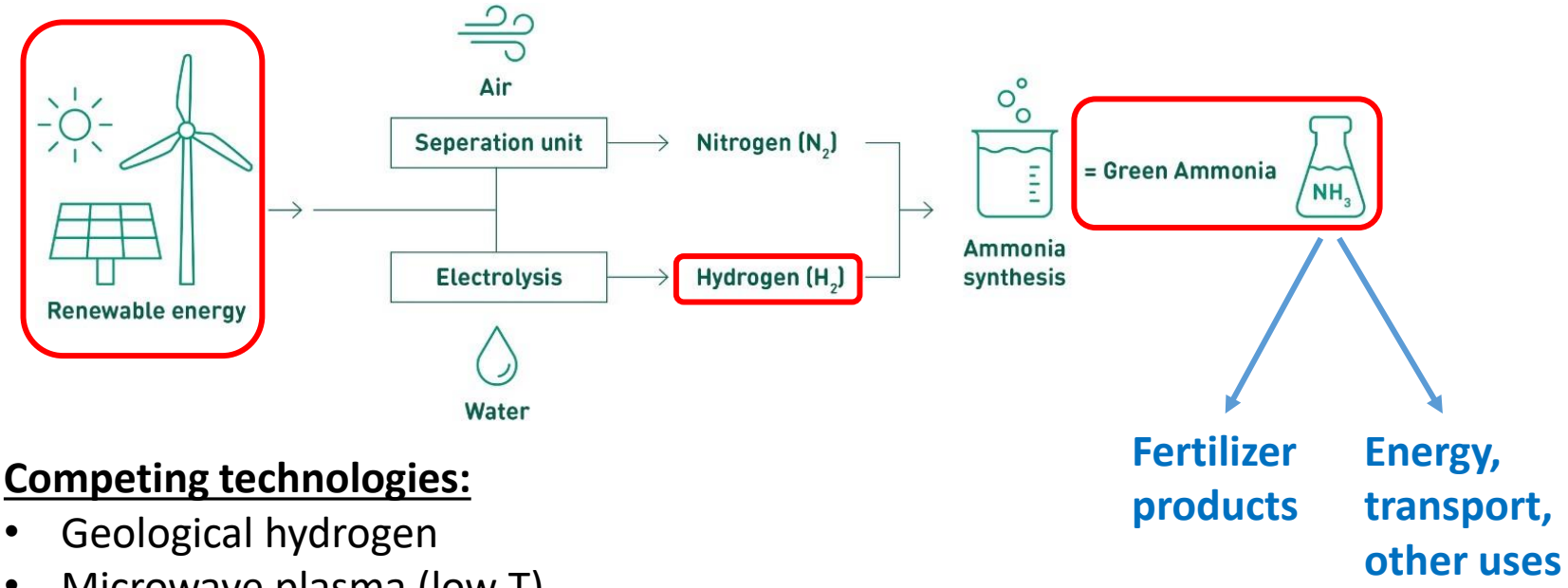
Decarbonizing the ammonia supply chain



Net zero by 2050: Gray → Blue (CCS) → Green ammonia

https://missionpossiblepartnership.org/wp-content/uploads/2022/09/Making-1.5-Aligned-Ammonia-possible.pdf

Green ammonia



Competing technologies:

- Geological hydrogen
- Microwave plasma (low T)
- EMF-assisted thermal catalysis (low T)
- .....

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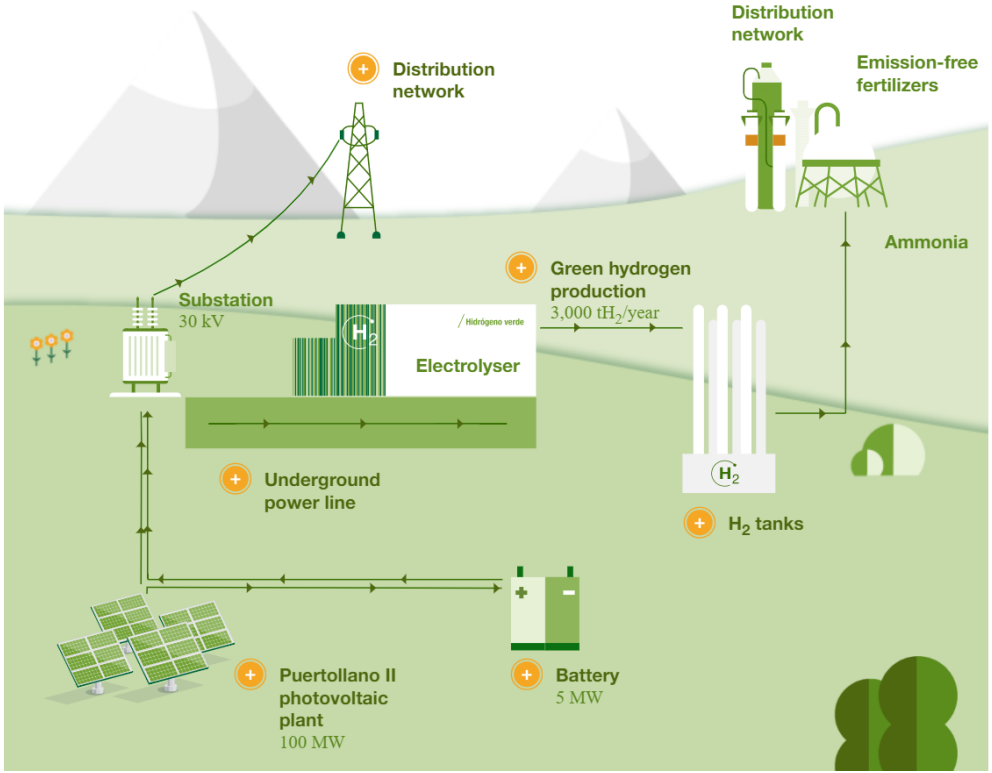
Green ammonia



Fertiberia

The age of 'cheap' N is probably over

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Small, modular green ammonia plants

talus renewables

kenya nut company

Naivasha, Kenya; 1 t of ammonia per day; 2-4 wk installation

Autonomous operation (remote monitoring) https://www.talusag.com/

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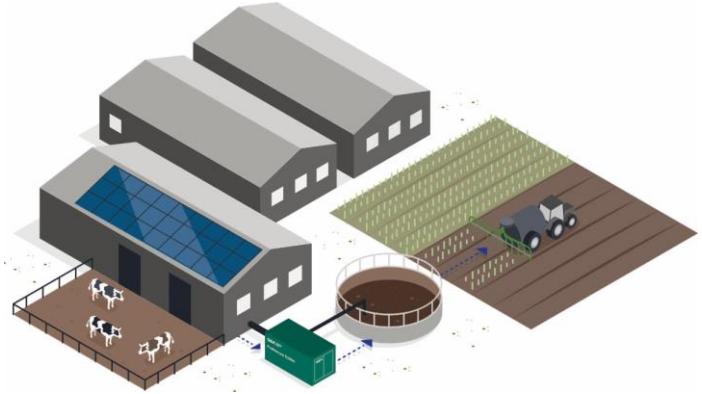
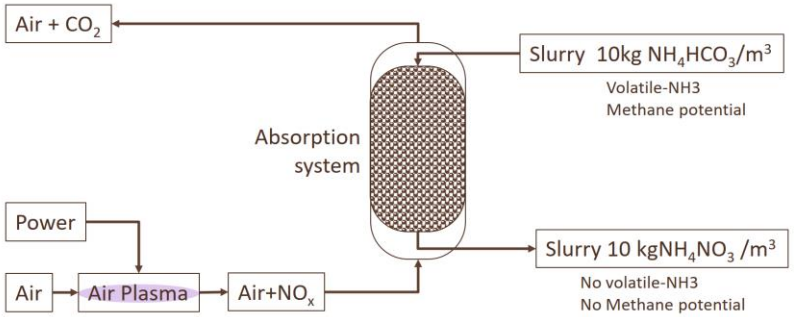
Plasma manure nitrogen enricher

roManure E2950





Developed by N2 Applied, Norway, https://n2applied.com/
Available as ProManure E2950 from GEA, Germany

N2 Applied

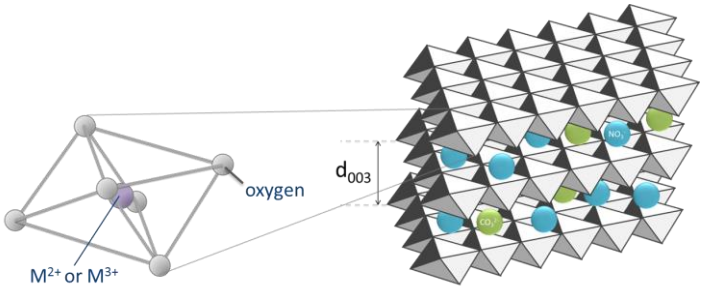
Big opportunities – many unknows

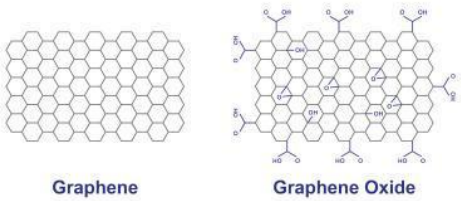
- Improved GHG budgets in different sectors (ag, transport, power)
- More diversified fertilizer production: big plants, small plants, indiv. farm units
- Less market dependency & volatility
- ‘Green’ price premiums? Overall economics?
- End products?: less urea – more nitrates, compounds (higher value)?

Fertiberia, Spanien

Novel fertilizers – the next 10 years

- Nanomaterials
- Layered double hydroxides
- Graphene-based materials
- Hydrogels
- Zeolites
- Biodegradable coatings
- Sulfur-polymer composites
- Metal-organic frameworks
- Microbiological products
- Biostimulants/bioactive substances
- “Smart” products (plant-triggered)





More know-how will be embedded in the product

Source: Mike McLaughlin, University of Adelaide

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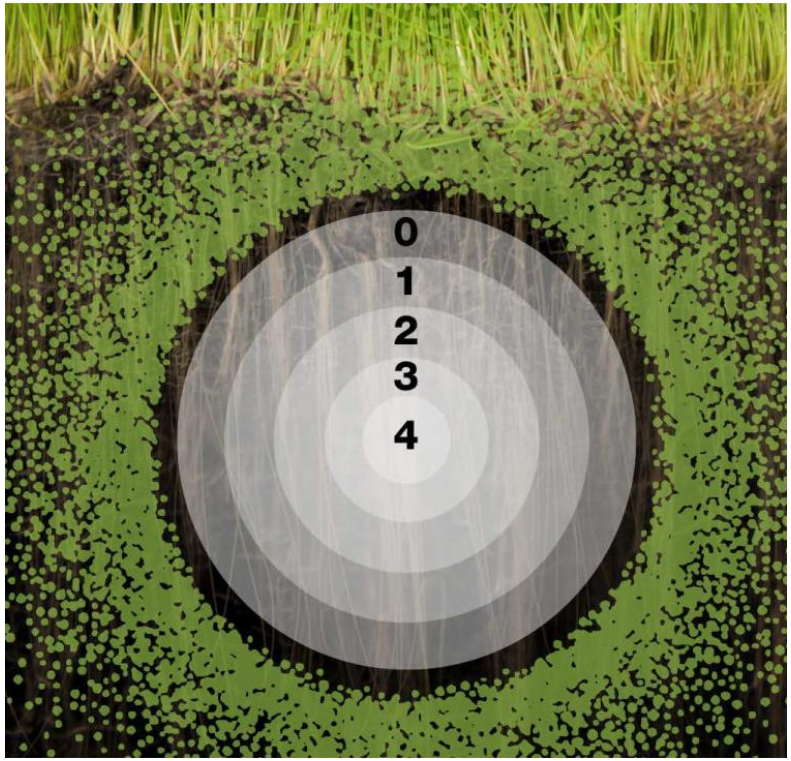
THE UNIVERSITY of ADELAIDE
FERTILISER TECHNOLOGY RESEARCH CENTRE

Smart fertilizers

- Tailored in composition (one or more nutrients)
- Economical in production and use
- Fully bio-degradable, safe
- Release aligned with plant growth: may be triggered by microbes or the plant itself



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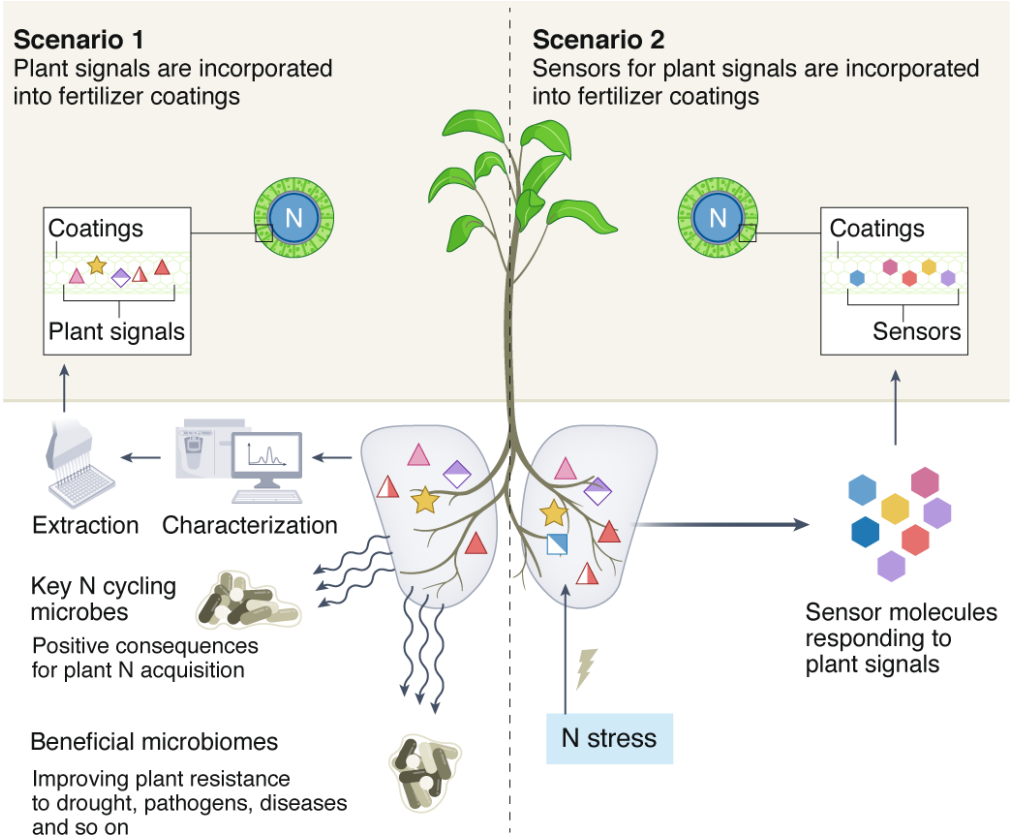
Smart fertilizers



Lam et al. 2022, *Nature Food* 3: 575-580

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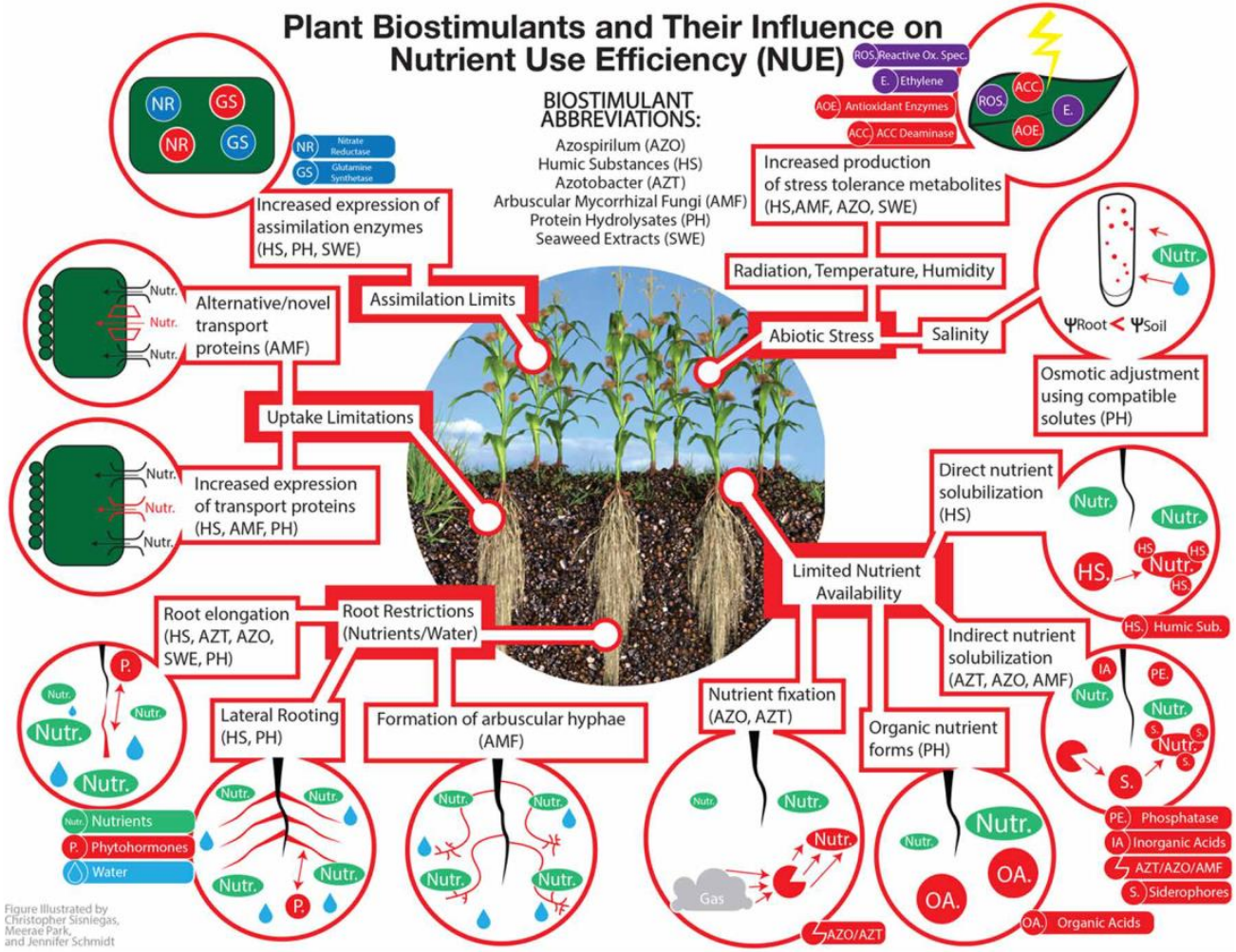

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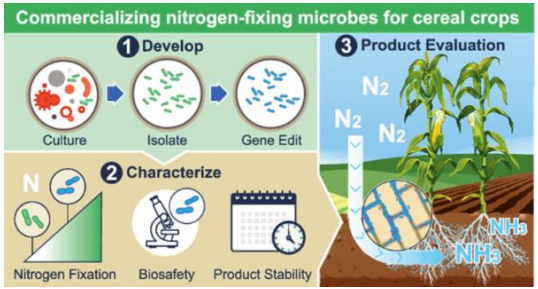
How well do biologicals work, and why?

Company claims



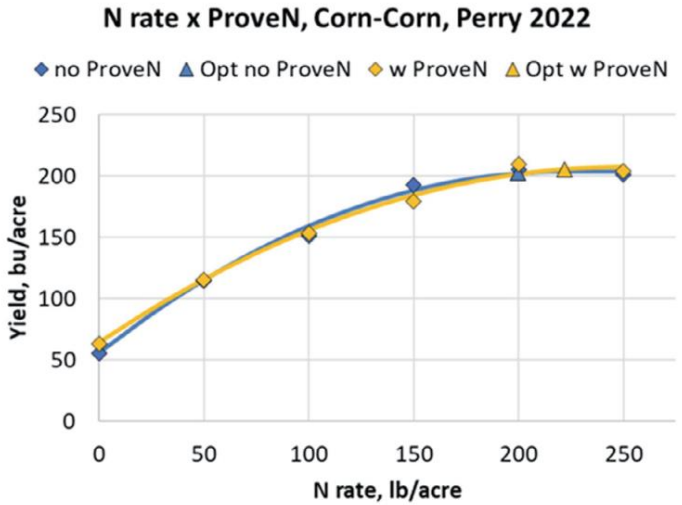
News release: “Pivot Bio's products in 2022:

- Helped farmers avoid 226,400 metric tons of carbon emissions
- Replaced >32,000 tons of N fertilizer
- Deliver greater ROI and higher margins for farmers”

https://www.pivotbio.com

vs

Independent field trials



- 61 site-years with and without microbial N fixing products in maize, wheat, sugar beet and canola in 10 states, North Central Region, USA
- **59 site-years had no yield increase or N saving from the microbial product.**

https://www.ndsu.edu/agriculture/sites/default/files/2023-04/sf2080.pdf

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Much needed

- Integrate genetics, physiologiy, chemistry, material science to design novel products
- Understand new modes of actions
- Rigorous field evaluation networks
- Improve national fertilizers policies

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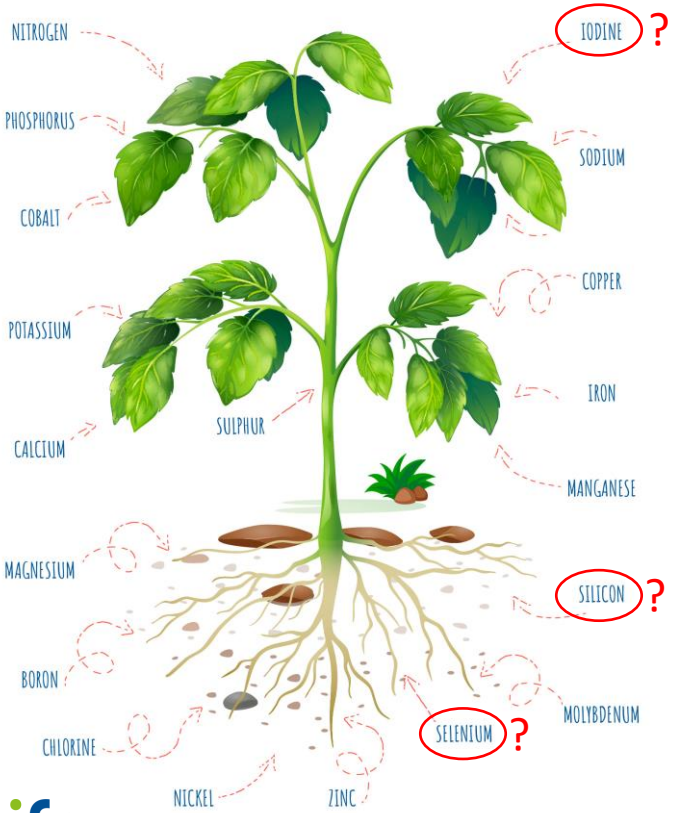
Rethinking plant nutrients



A mineral plant nutrient is an element which is essential or beneficial for plant growth, development or the quality attributes of the harvested product.

Plant Soil
https://doi.org/10.1007/s11104-021-05171-w

SPECIAL ISSUE S97 - 30 YEARS

Check for updates

What is a plant nutrient? Changing definitions to advance science and innovation in plant nutrition

Patrick H. Brown · Fang-Jie Zhao · Achim Dobermann

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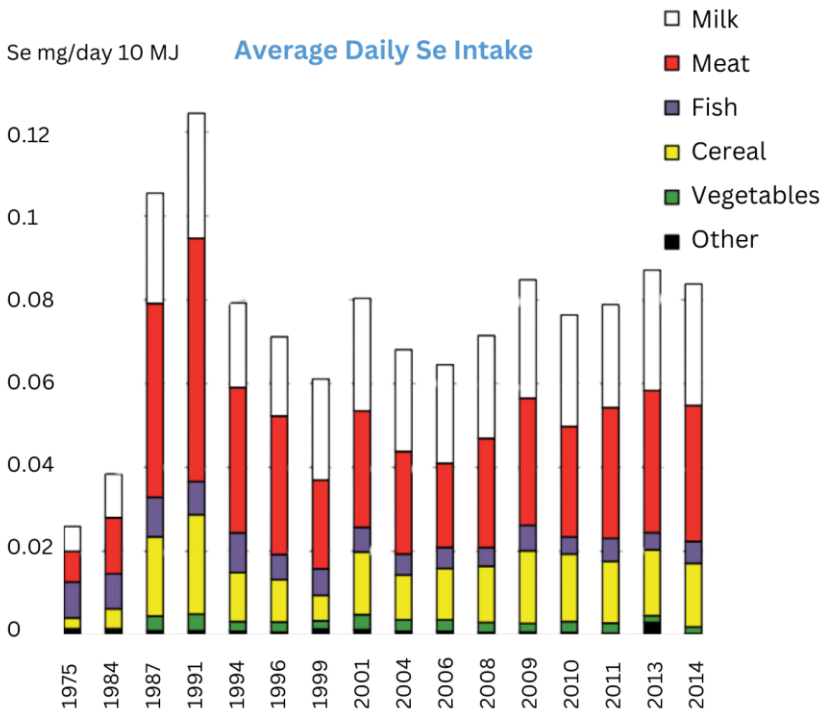
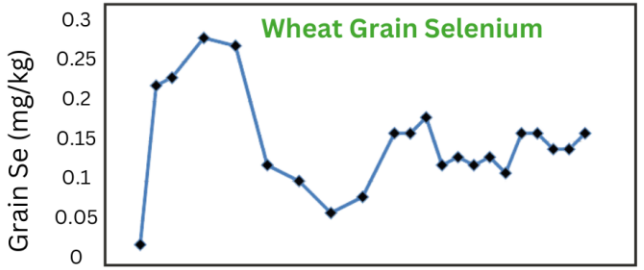
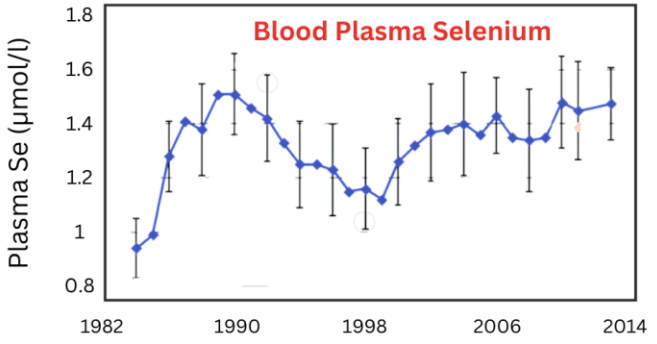
Selenium enrichment through fertilizers in Finland







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Fertilizer Se enrichment levels (mg Se/kg fertilizer)

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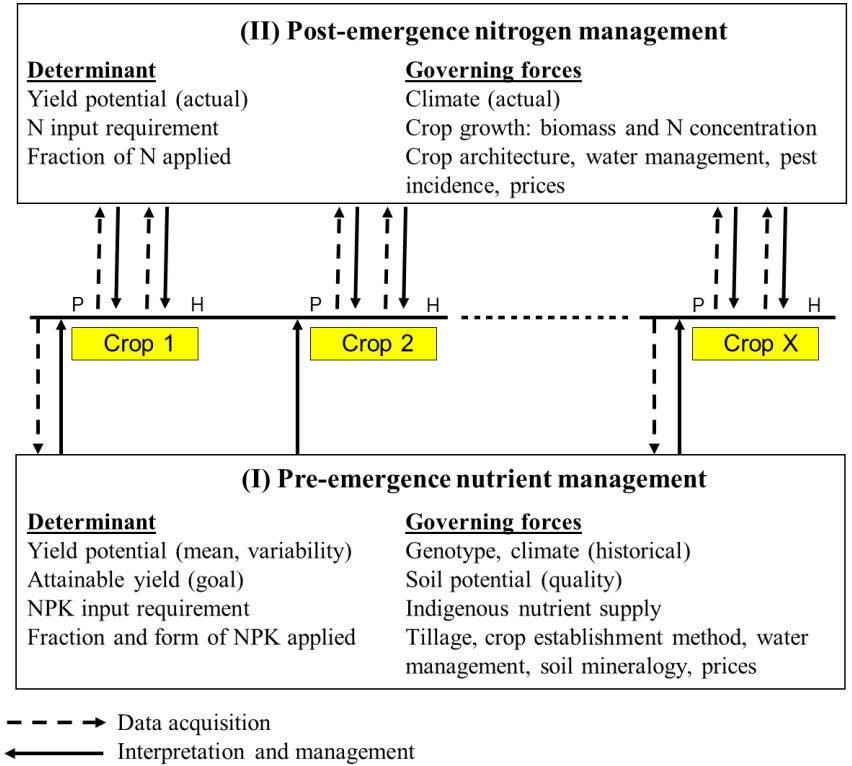
Limitations of current nutrient recommendations



Dobermann, A. & Cassman, K.G. 2002. Plant nutrient management for enhanced productivity in intensive grain production systems of the United States and Asia. Plant Soil 247: 153-175. (modified)

Common limitations:

- Single field, single crop, single nutrient
- Heavy reliance on soil testing
- Algorithms that do not account for many factors driving crop response to nutrients
- Fails to factor in uncertainty and communicate risk to farmers
- Little performance feedback for learning and local fine-tuning

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How to reach millions of farmers?

+25 years of research & extension efforts: limited reach

New opportunities:

- Artificial intelligence
- Precision application of nutrients

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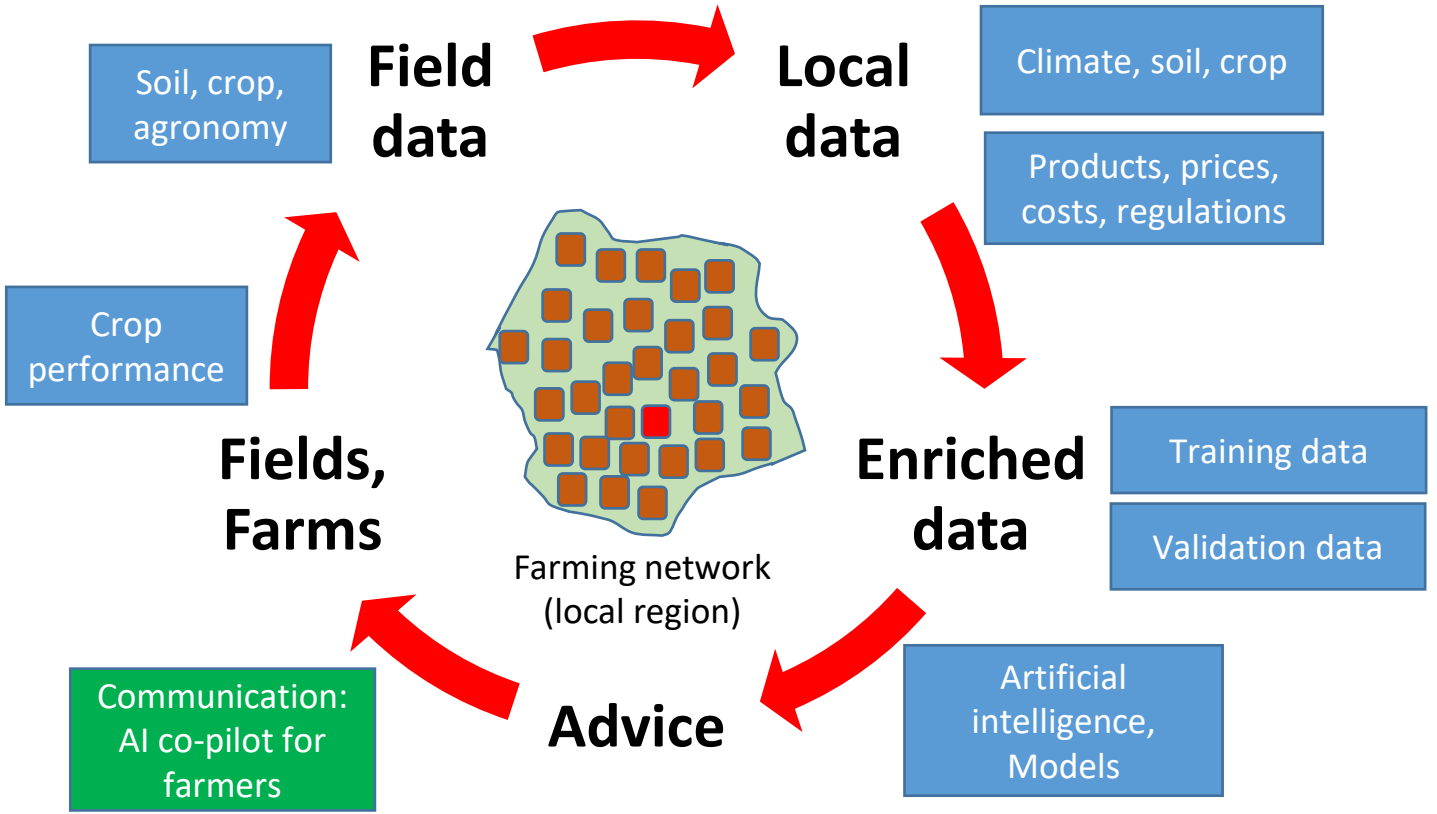
Data- and AI-driven, self-learning crop nutrition advisory



Key requirement: continuous collection, processing and sharing of field data

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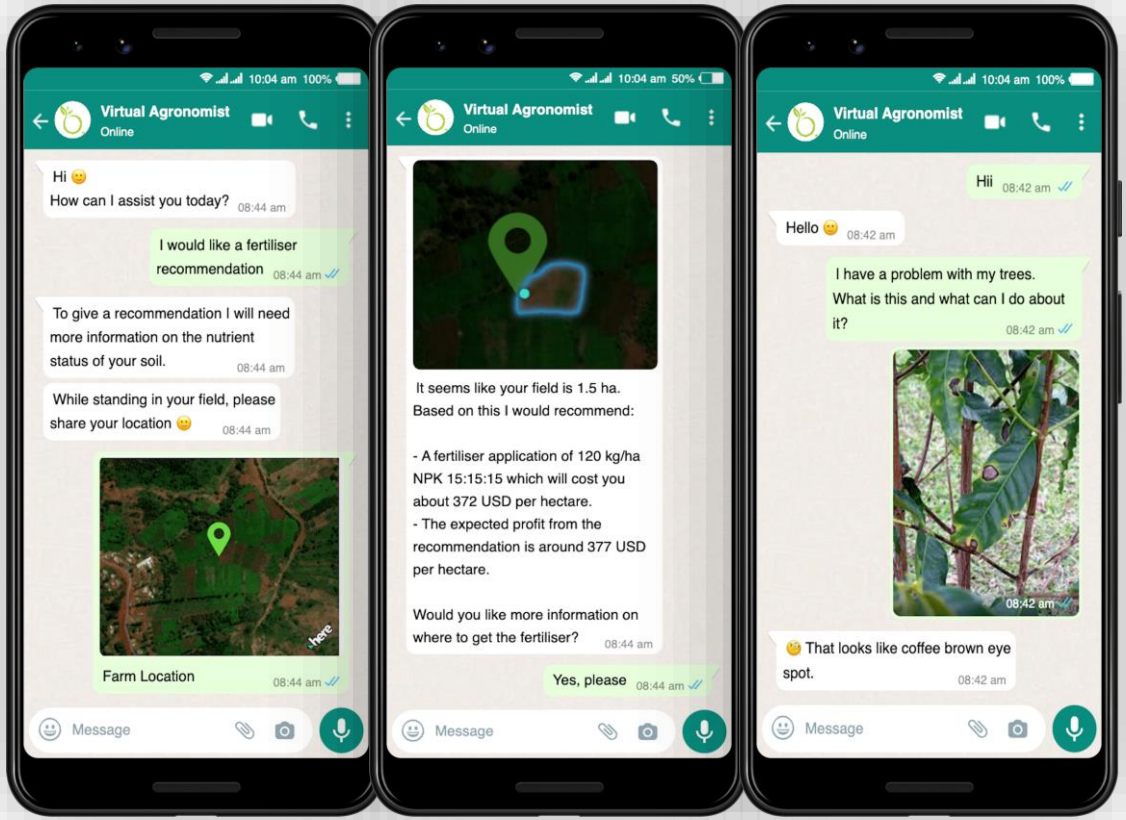
AI enables direct communication with farmers via WhatsApp

Virtual Agronomist

- Natural language interface
- Iteratively prompts and coaches farmers
- Series of tools for common tasks, e.g. SSNM rec.
- Ask any question
- Tailored advice, at scale, throughout the season
- Any crop, any farm, anywhere



iSDA AFRICA

2022 CROP ROBOTICS LANDSCAPE

The Mixing Bowl | Better Food Ventures

University of California Agriculture and Natural Resources

Chris Taylor
chris@mixingbowlhub.com

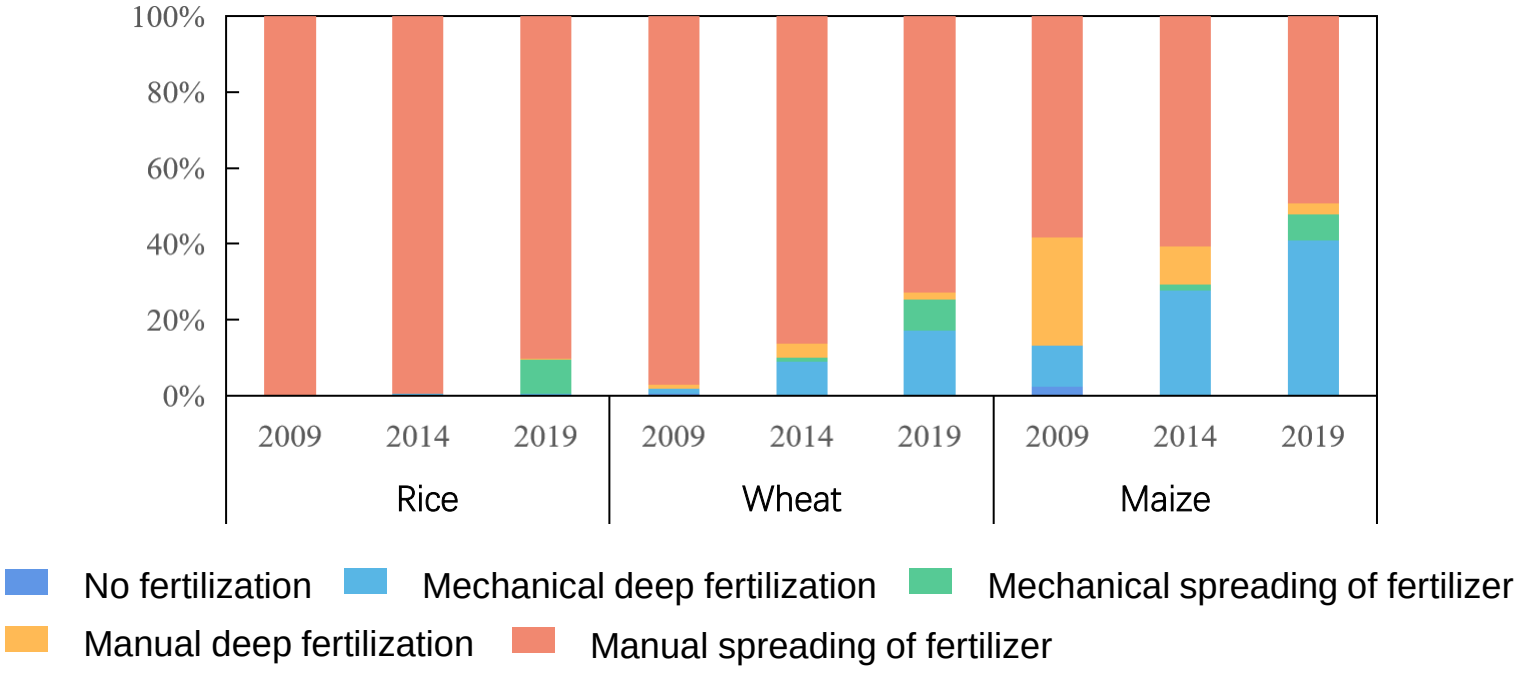
www.MixingBowlHub.com

Michael Rose
michael@betterfoodventures.com

THE VINE

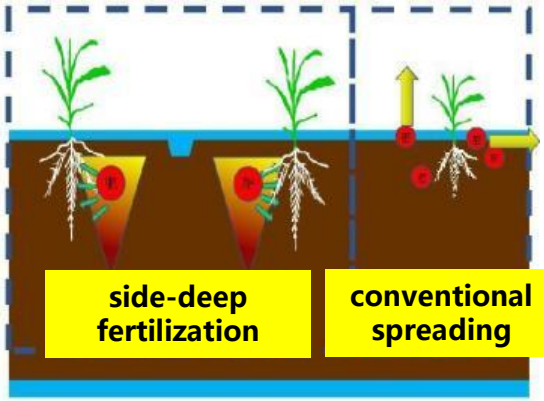
Mechanized fertilizer application

Adoption of mechanized basal fertilizer application in China



Source: Weifeng Zhang, China Agricultural University

Precise fertilizer application



Sowing and fertilization

Transplanting and fertilization

- Less applications (lower cost & fertilizer usage)
- Improves fertilizer use efficiency by over 20%
- Increases rice yield by approximately 10%.
- Extends the retention time of N in the soil, reducing ammonia volatilization losses by >60%

Fertilizer products for mechan. application in rice?

Source: Weifeng Zhang, China Agricultural University

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Precise fertilizer application: Drones

Granular fertilizer

- High nutrient content
- For NPK
- Environment has a small impact

Load 40 kg

Spreading System

Electric Power System

Spraying System

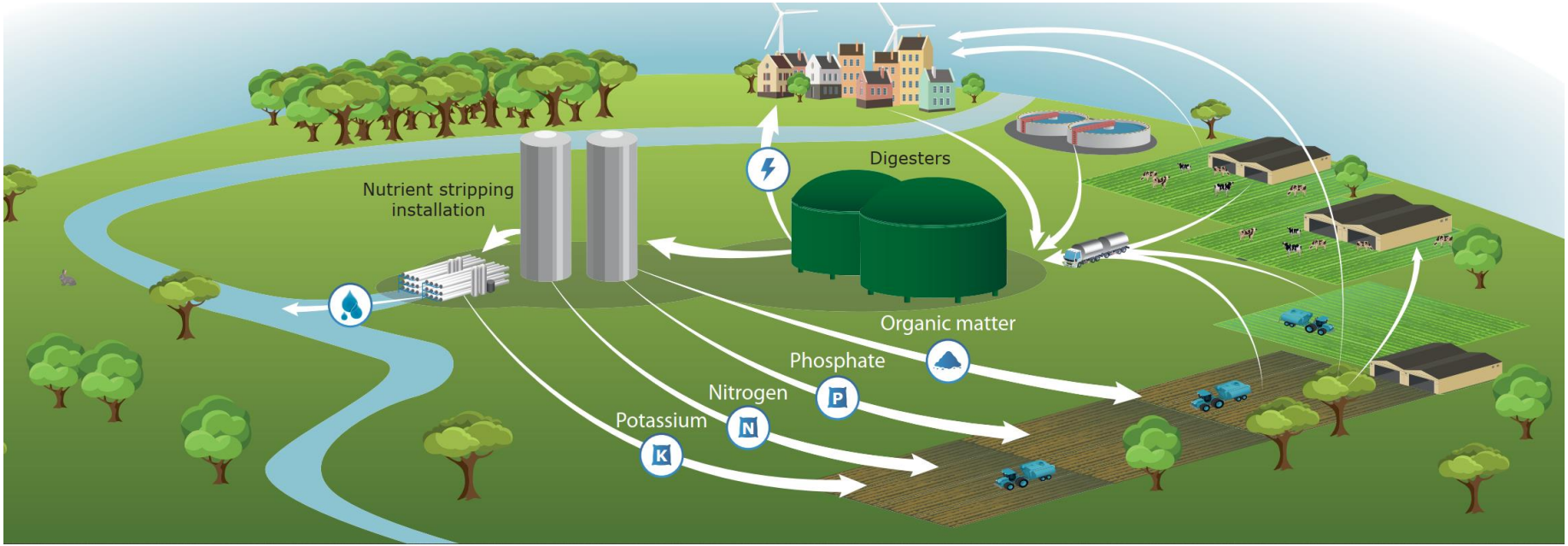
Foliar fertilization

- Low nutrient content
- For micronutrients
- Environment has a big impact

Fertilizer products for UAV fertilization?

Source: Weifeng Zhang, China Agricultural University

Recover and recycle nutrients from major waste streams



https://systemicproject.eu/

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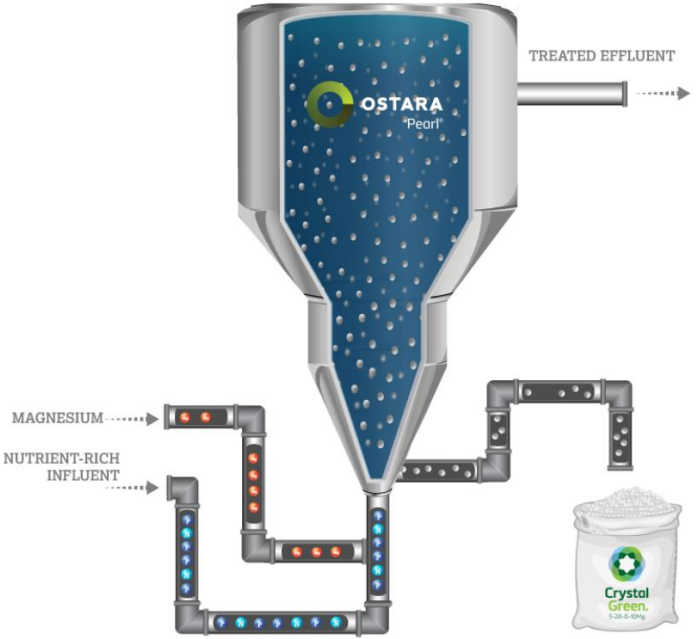
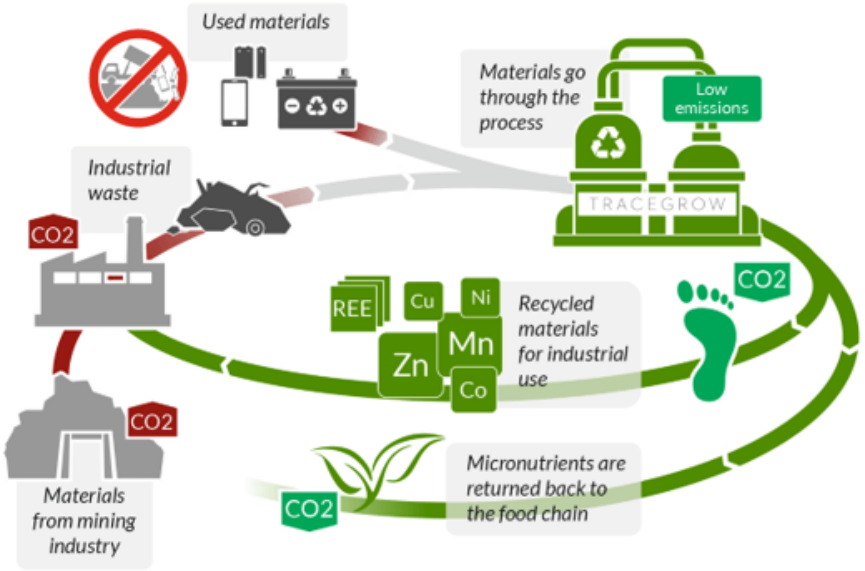
Recover and recycle nutrients from major waste streams



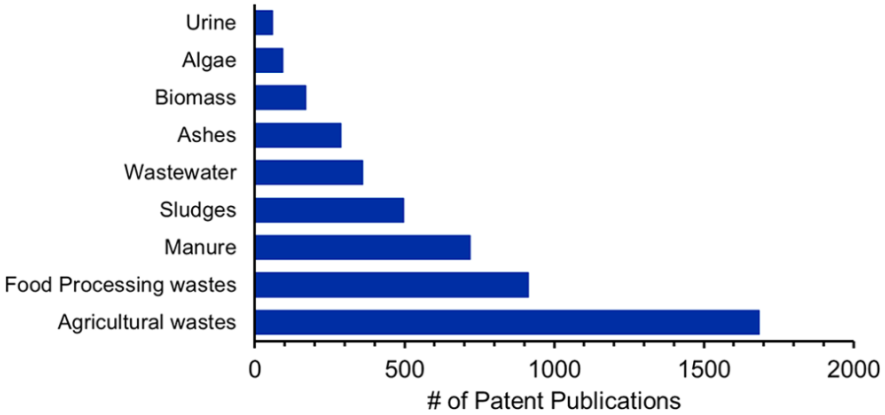
$MgNH_4PO_4*6H_2O$

Phosphorus recovery
https://ostara.com/



Micronutrients recovery,
https://www.tracegrow.com/

Recover and recycle nutrients from major waste streams



Patents 2001-2021

What can be economically recovered from straw and other biomass?

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2040s

- 9 billion people - 110 million t of fertilizer N (crops)
- ‘Green’ nitrogen
- Smart fertilizers + AI-driven crop advice + precise application
- Global NUE on cropland ~70%
- More closed nutrient cycles
- More balanced crop nutrition & targeted micronutrient enrichment

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